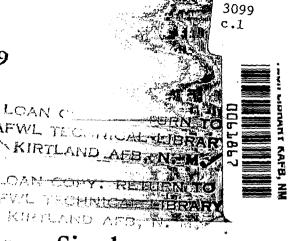
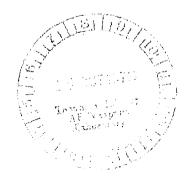
NASA Contractor Report 3099



Rotary Balance Data for a Single-Engine Trainer Design for an Angle-of-Attack Range of 8° to 90°

Paul Pantason and Waldo Dickens

CONTRACT NAS1-14849 AUGUST 1979







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Paul Pantason and Waldo Dickens Bibrle Applied Research, Inc. Jericho, New York

Prepared for Langley Research Center under Contract NAS1-14849



Scientific and Technical Information Branch

1979

SUMMARY

Aerodynamic characteristics obtained in a rotational flow environment utilizing a rotary balance located in the Langley spin tunnel are presented in plotted form for a 1/6-scale, single-engine trainer airplane model. The configurations tested included the basic airplane, various wing leading-edge devices, elevator, aileron and rudder control settings as well as airplane components. Data are presented without analysis for an angle-of-attack range of 8° to 90° and clockwise and counter-clockwise rotations covering an $\frac{\Omega b}{2V}$ range from 0 to 0.85.

INTRODUCTION

The NASA Langley Research Center has initiated a broad general aviation stall/spin research program which includes spintunnel and free-flight radio control model tests, as well as full-scale flight tests for a number of configurations typical of light, general aviation airplanes. To support this effort, rotary balance wind tunnel force tests covering these same configurations will be conducted to establish a data base for analysis of model and full-scale flight results, and to develop design charts for desirable stall/spin characteristics.

A 1/6-scale, single-engine trainer airplane model, having a low-wing location was tested in a rotational flow environment utilizing a rotary balance located in the Langley spin tunnel. This report presents the data obtained for the basic configuration, various wing leading-edge devices, elevator, aileron and rudder control settings as well as airplane components.

SYMBOLS

The units for physical quantities used herein are presented in the International System of Units (SI) and U.S. Customary Units. The measurements were made in the U.S. Customary Units; equivalent dimensions were determined by using the conversion factors given in reference 1.

- b wing span, m (ft)
- ē mean aerodynamic chord, cm (in.)
- C_{L} lift-force coefficient, $\frac{Lift\ force}{qS}$
- C_{N} normal-force coefficient, $\frac{Normal\ force}{qS}$
- C_{A} axial-force coefficient, $\frac{Axial\ force}{qS}$
- C_{Y} side-force coefficient, $\frac{\text{Side force}}{\text{qS}}$
- C_{ℓ} rolling moment coefficient, Rolling moment qSb
- C_{m} pitching-moment coefficient, $\frac{\text{Pitching moment}}{\text{qSC}}$
- C_n yawing-moment coefficient, $\frac{\text{Yawing moment}}{\text{qSb}}$
- q free-stream dynamic pressure, N/m2 (lb/ft2)
- S wing area, m² (ft²)
- V free-stream velocity, m/sec (ft/sec)
- α angle of attack, deg
- β angle of sideslip, deg
- Ω angular velocity about spin axis, rad/sec
- $\frac{\Omega b}{2V}$ spin coefficient, positive for clockwise spin
- $\boldsymbol{\delta}_{\text{a}}$ aileron deflection, positive when right aileron is down

$$(\delta_{a} - \delta_{a})/2$$
, deg

 $\delta_{\mathbf{p}}$ elevator deflection, positive when trailing edge is down, deg



 $\boldsymbol{\delta}_{\text{r}}$ -rudder deflection, positive when trailing edge is to left, deg

Abbreviations:

cg center of gravity

LE leading edge

SR spin radius

TEST EQUIPMENT

A rotary balance measures the forces and moments acting on an airplane while subjected to rotational flow conditions; the background for this apparatus is discussed in reference 2. A photograph and sketch of the rotary balance apparatus installed in the Langley spin tunnel are shown in figures 1 and 2, respectively. The rotating portion of the balance system, mounted on a horizontal supporting boom which is hinged at the wall, is moved from the wall to the center of the tunnel by cables. The rotary arm of the balance system, which rotates about a vertical axis, is attached to the outer end of the horizontal supporting boom and is driven by a drive shaft through couplings and gears.

A test model is mounted on a strain gauge balance which is affixed to the bottom of the rotary balance apparatus. Controls located outside the tunnel are used to activate motors on the rig which position the model to the desired attitude. The angle-of-attack range of the rig is 8 to 90 degrees and the sideslip angle range is ± 15 degrees. The spin radius and the lateral displacement motors allow the operator to position the moment center of

the balance on the spin axis or at a specific distance from the spin axis. This is done for each combination of angle of attack and sideslip angle. The general practice is to mount the moment center of the balance at the cg location about which the aerodynamic moments are desired. Electrical current from the balance, and to the motors on the rig, is conducted through slip-rings located at the rig head. Examples of how the rig is positioned for different angle of attack and sideslip angles are shown in figures 2a and 2b, respectively.

The model can be rotated up to 90 rpm in either direction. By using different rotational speeds and a specific airflow in the tunnel, the motions of a steady spinning airplane can be simulated. The aerodynamic forces and moments can then be measured for values of $\frac{\Omega b}{2V}$, including the case of $\frac{\Omega b}{2V}$ =0, where static aerodynamic forces and moments can be obtained.

A NASA six-component strain gauge balance is mounted inside the model and measures the normal, lateral and longitudinal forces and the yawing, rolling and pitching moments acting about the model body axis. The interactions that exist between the six components are available from balance calibration tests and are accounted for after the balance voltages are converted to forces and moments.

The data acquisition, reduction and presentation system for the rotary balance set-up is composed of a 12-channel scanner/ voltmeter, a mini-computer and a plotter. With this equipment, on-line digital print-out and/or graphical plots of data are possible.

TEST PROCEDURES

Rotary aerodynamic data are obtained in two steps. The first step is to record the inertial forces and moments (tares) acting on the model at different attitudes and rotational speeds. To accomplish this, a covered bird-cage like structure is mounted to the upper rig which encloses the model without touching it. In this manner, the air immediately surrounding the model is rotated with it. As the rig is rotated at the desired attitude and rate, the inertial forces and moments generated by the model are measured and stored on magnetic tape for later use.

The second step in the data-gathering process is to measure aerodynamic and inertial forces at different attitudes and rotational speeds for a selected tunnel velocity with, of course, the cage structure removed. The tares are subtracted from these values, and the remaining aerodynamic forces and moments are then converted to coefficient form and stored on magnetic tape.

MODEL

A 1/6-scale fiberglass/aluminum model of a configuration considered to be a typical low-wing, single-engine trainer airplane was tested in the present study. A three-view drawing of this model is shown in figure 3, dimensional characteristics of the model are presented in Table I, and a photograph of the model installed on the rotary balance located in the Langley spin tunnel is presented in figure 1.

The model control surfaces could be set at any position prior to the test. The maximum deflections for the control surfaces were:

Elevator, deg 20 up, 15 down

Rudder, deg 28 right, 28 left

Aileron, deg 20 up, 20 down

TEST CONDITIONS

The tests were conducted in the spin tunnel at a tunnel velocity of 7.62m/sec (25 ft/sec) which corresponds to a Reynolds number of 145,000 based on the model mean aerodynamic chord. Unless noted otherwise in Table II, all the configurations were tested through an angle-of-attack range of 8 to 90° at a zero sideslip angle with the spin axis passing through the full-scale airplane cg location of .25 \bar{c} for angles of attack above 30° . For angles of attack below 35° , the spin axis was set 91.4 cm (36 in.) forward of the cg. Consequently, data was obtained for both a 0 and 91.4 cm (36 in.) spin radius at angles of attack of 30 and 35° . At each spin attitude, measurements were obtained for nominal $\frac{\Omega b}{2V}$ values of .1, .2, .3, .4, .45, .55, .65, .75 and .85 in both clockwise and counter-clockwise directions, as well as for $\frac{\Omega b}{2V}$ =0 (static value).

DATA PRESENTATION

Table II identifies the configurations tested and the corresponding appendix figure numbers which present the aerodynamic data. The aerodynamic coefficients vs. $\frac{\Omega b}{2V}$ are presented for each configuration in six sequentially numbered

figures in the following order: C_n , C_{ℓ} , C_m , C_N , C_{γ} and C_{λ} . Each figure, in turn, consists of four pages which present the subject aerodynamic coefficient vs. $\frac{\Omega b}{2V}$ for the following angles of attack and spin radii, unless noted otherwise in Table II.

- a) α = 8, 10, 12, 14, 16 deg SR= 91.4 cm (36 in.)
- b) $\alpha = 18$, 20, 25, 30, 35 deg SR= 91.4 cm (36 in.)
- c) $\alpha = 30$, 35, 40, 45, 50 deg SR= 0
- d) α = 55, 60, 70, 80, 90 deg SR= 0

All the moment data are presented for a cg position of 0.25c.

Lift coefficient as a function of angle of attack for zero rotation rate is presented at the end of the Appendix for several configurations cited in Table II.

REFERENCES

- Mechtly, E.C.: The International System of Units Physical Constants and Conversion Factors. NASA SP-7012, 1973.
- 2. Bihrle, William, Jr.; Hultberg, Randy S.; and Mulcay, William: Rotary Balance Data for a Typical Single-Engine Low-Wing General Aviation Design for an Angle-of-Attack Range of 30^o to 90^o. NASA CR 2972, 1978.

TABLE I DIMENSIONAL CHARACTERISTICS OF THE BASIC MODEL
Overall length, m (ft) 1.46 (4.79)
Wing:
Span, m (ft)
Area, m^2 (ft ²)
Root chord, cm (in.)
Tip chord, cm (in.)
Mean aerodynamic chord, cm (in.) 27.66 (10.89
Leading edge of C, distance rearward of leading
edge of root chord, cm (in.) 1.98 (.78)
Aspect ratio 6.21
Taper ratio 0.50
Dihedral, deg 7.0
Incidence:
Root, deg 4.0
Tip, deg 1.0
Airfoil section:
Root NASA 23016.5
Tip
Horizontal tail:
Span, m (ft)
Area, m^2 (ft ²)
Incidence, deg
Airfoil section NASA 0008.2 (modified)
Vertical tail:
Area, m^2 (ft ²)
Sweepback at leading edge, deg
Aspect ratio 1.44
Leading edge canted left, deg 1.0
Airfoil section NASA 0006 7 (modified)

with ventrals, strakes and engine stacks off

with 4.06cm (1.6in) span outboard LE wing droop tab

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 $^{^{\}rm a}$ C, vs. α presented in figure A85.

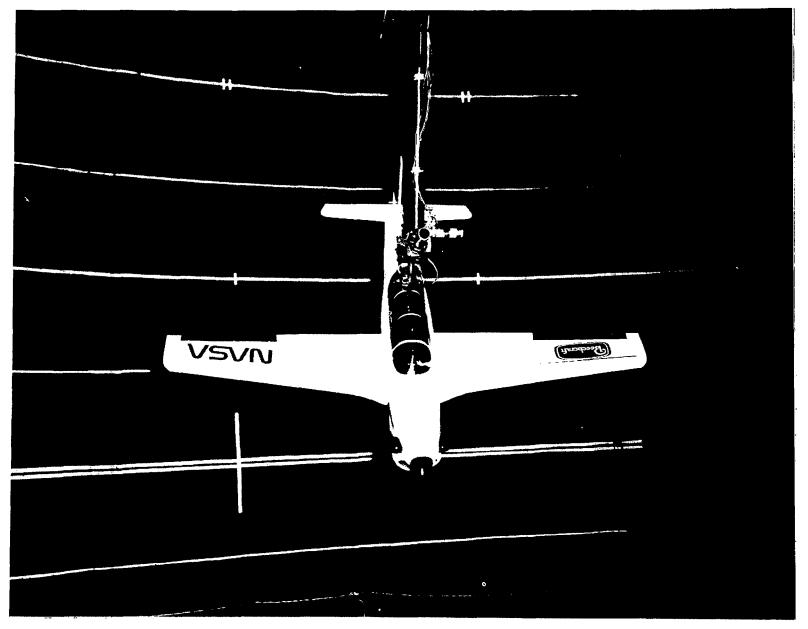
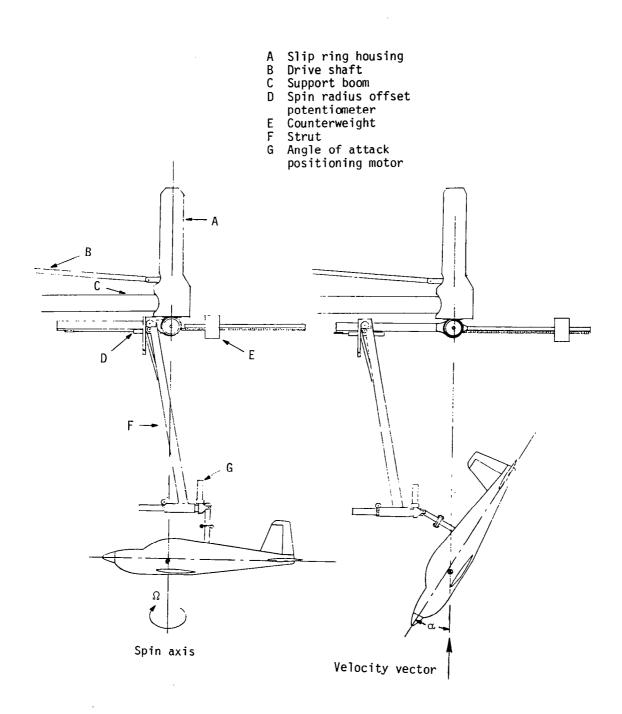
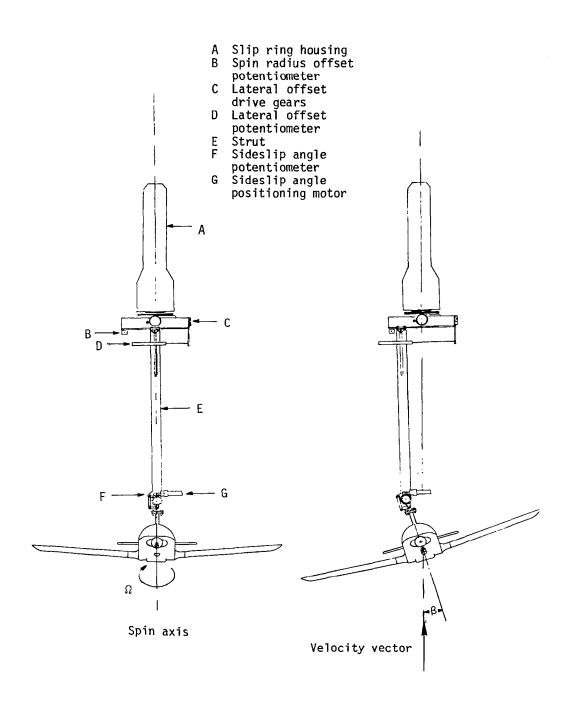


Figure 1.- Photograph of 1/6-scale model installed on rotary balance apparatus.



(a) Side view of model.

Figure 2.- Sketch of rotary balance apparatus.



(b) Front view of model.

Figure 2.- Concluded.

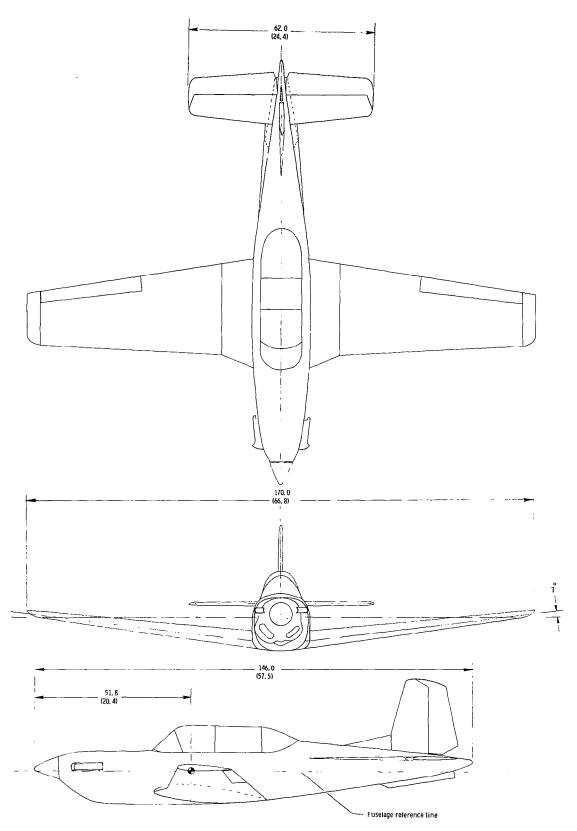


Figure 3. - Three-view drawing of basic 1/6-scale low-wing trainer. Center-of-gravity positioned at 0.25c. Dimensions are given in centimeters (inches), model scale.

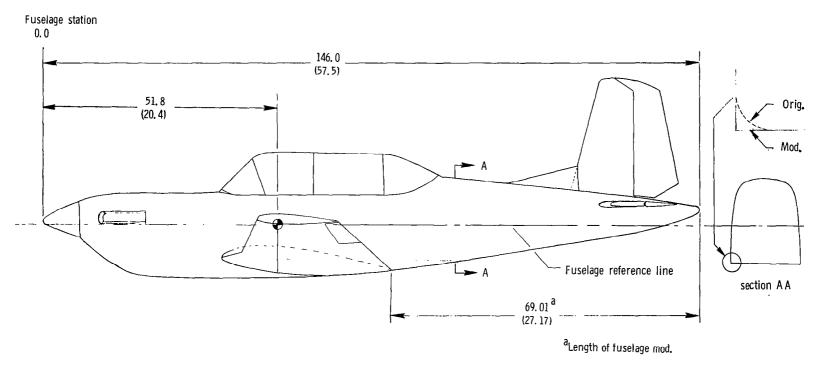


Figure 4. - Fuselage shape modification tested on model. Dimensions are given in centimeters (inches), model scale.

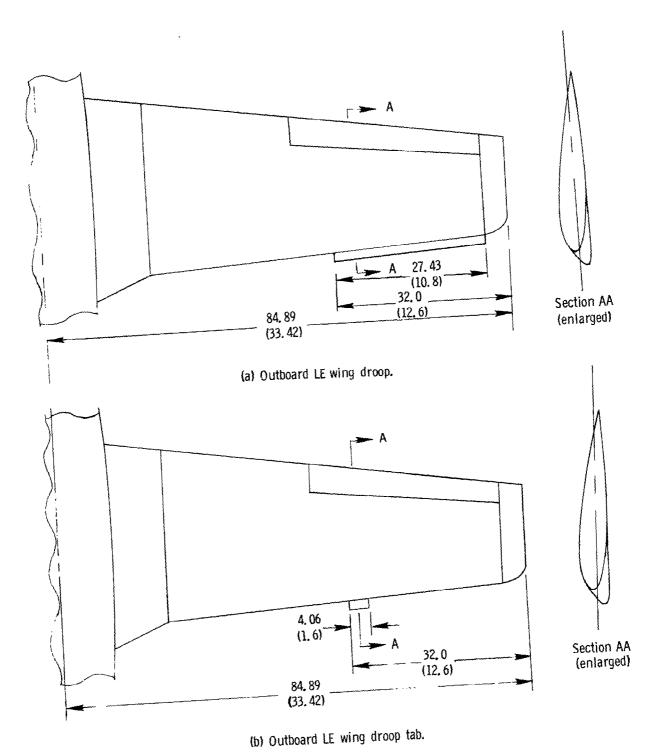
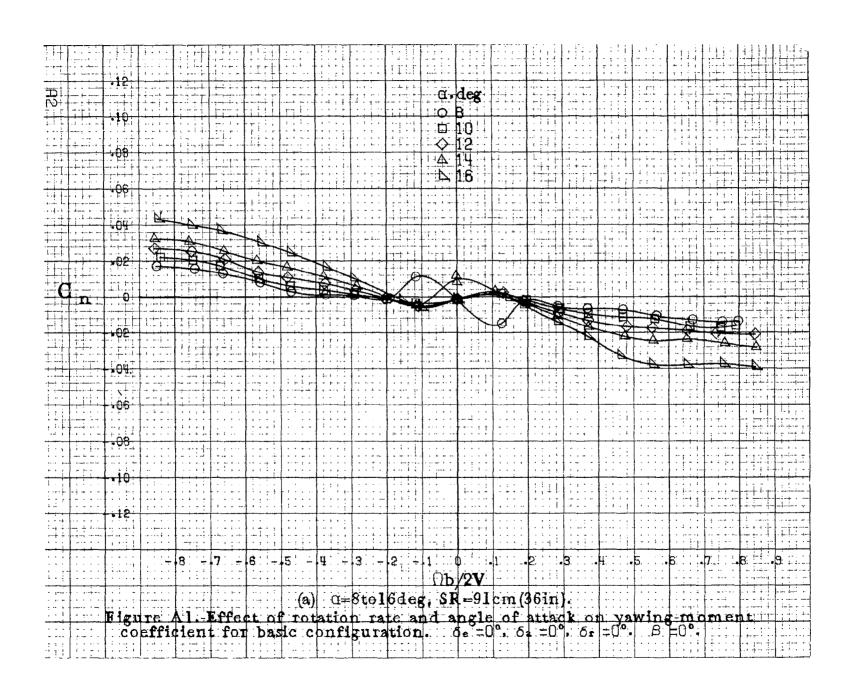
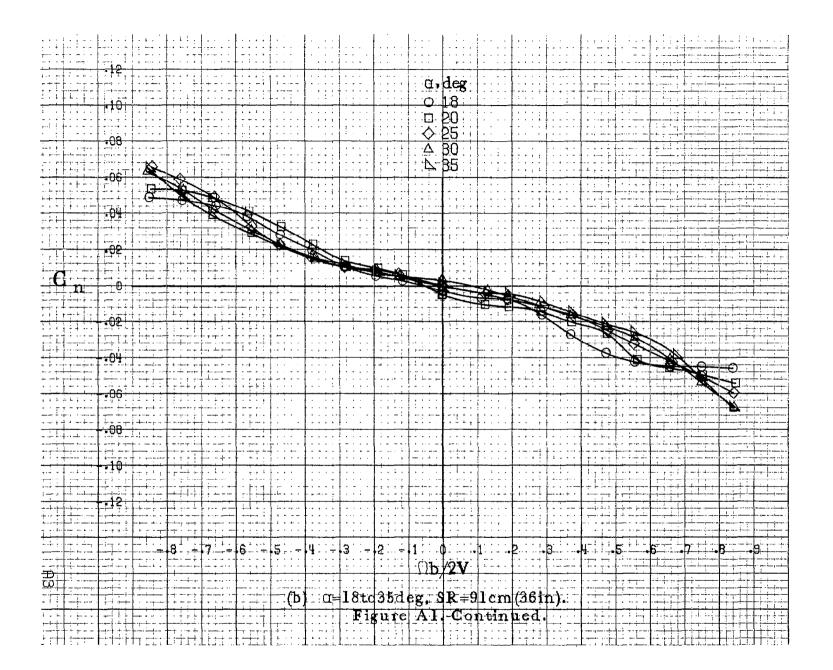
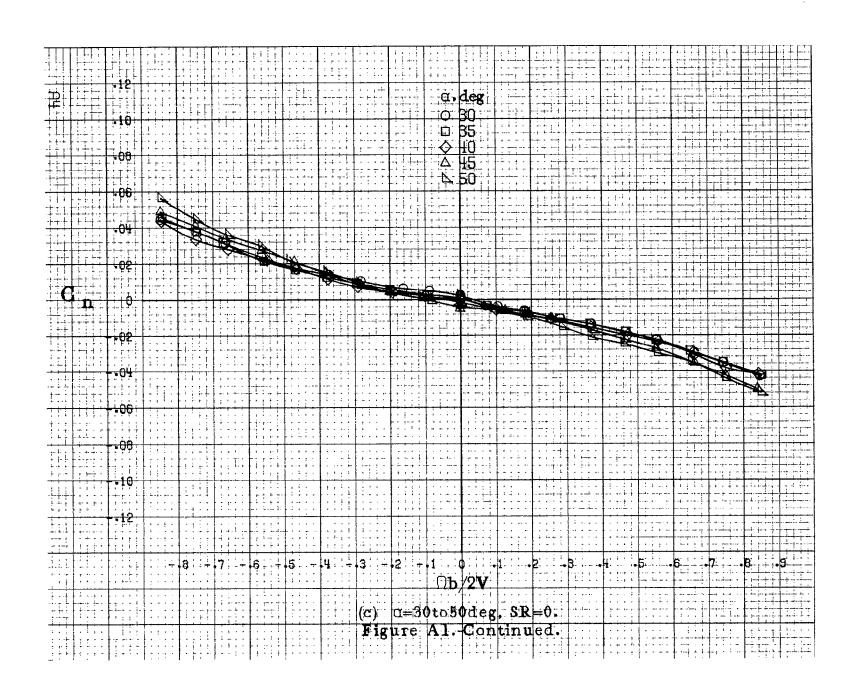


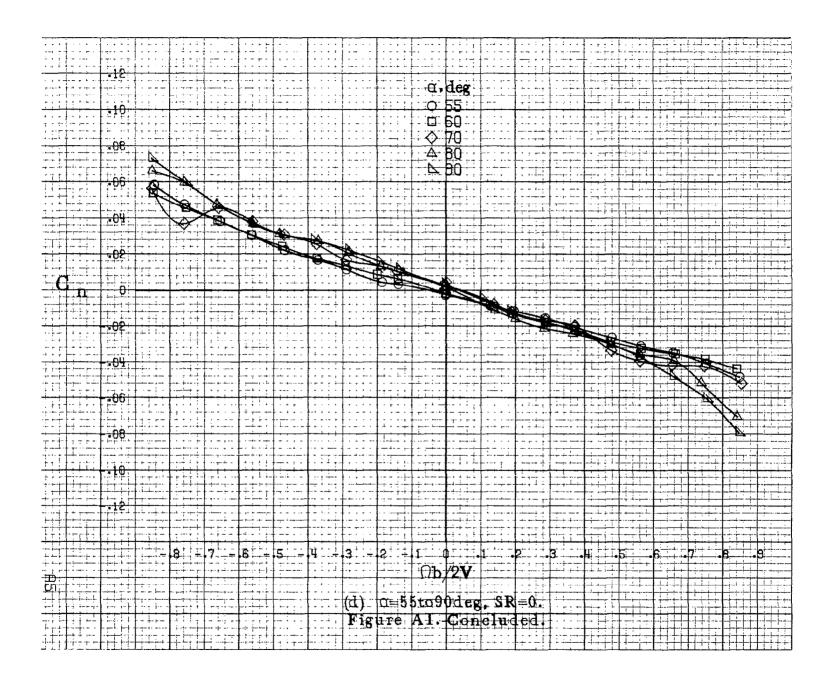
Figure 5. - Wing leading-edge modifications tested on model. Dimensions are given in centimeters (inches), model scale.

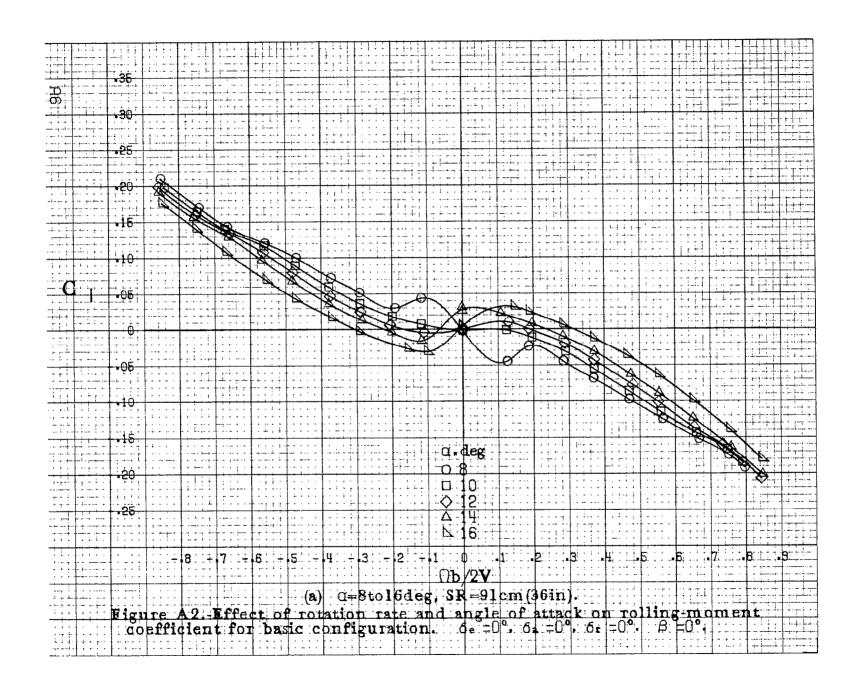
APPENDIX

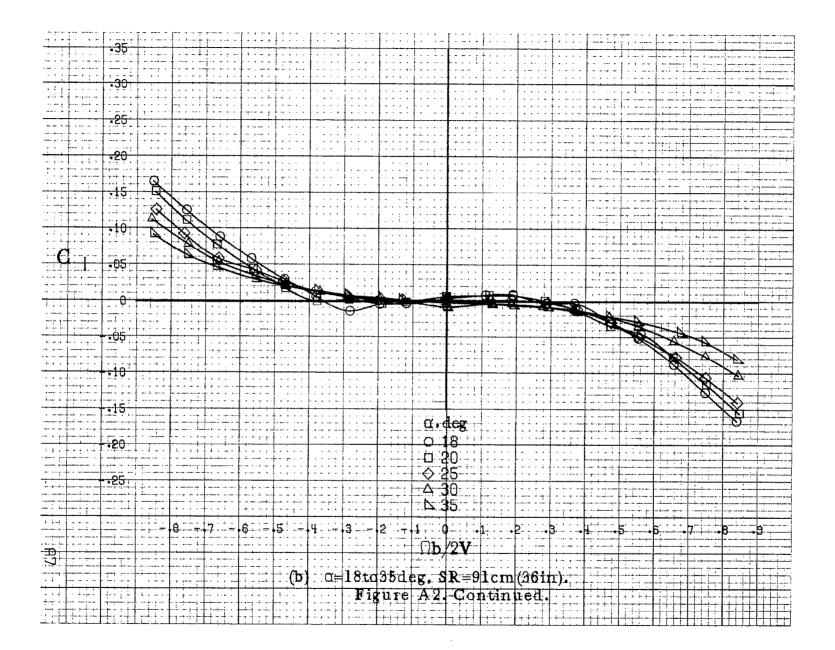


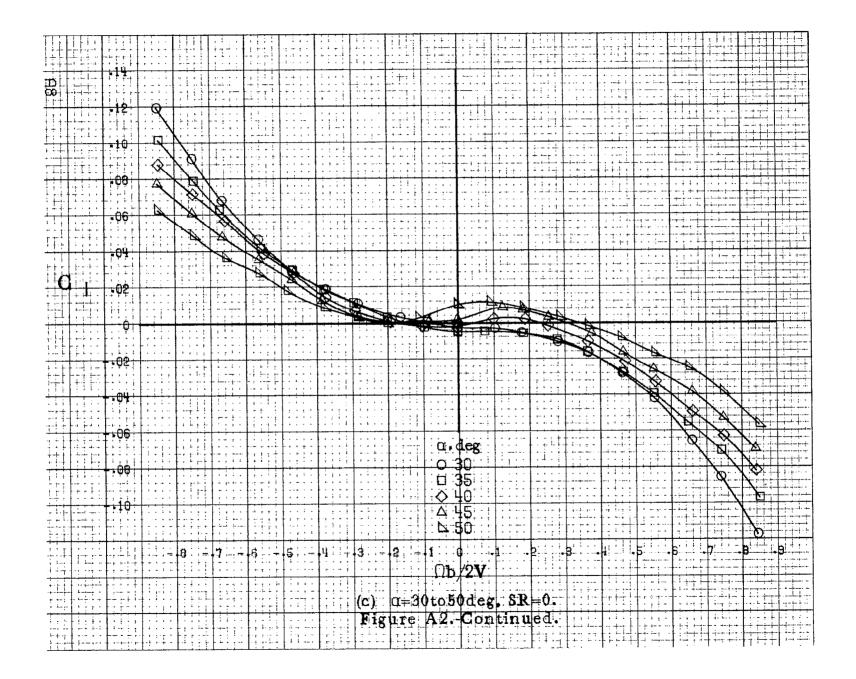




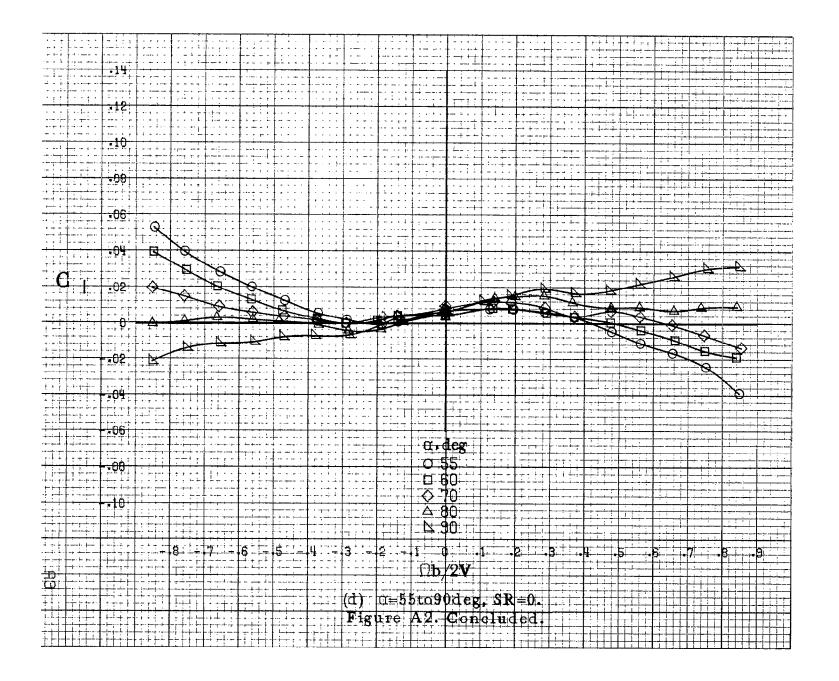


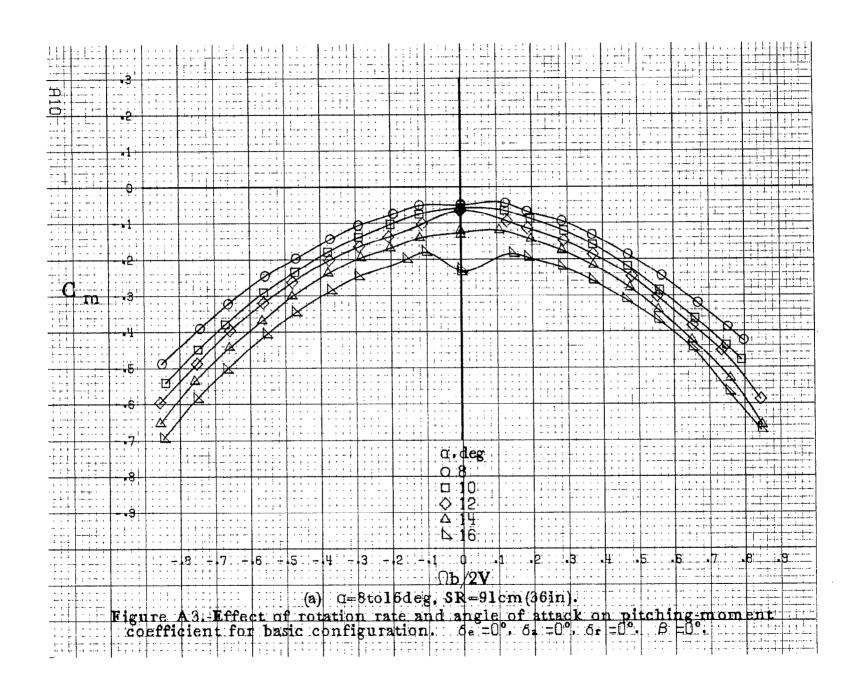




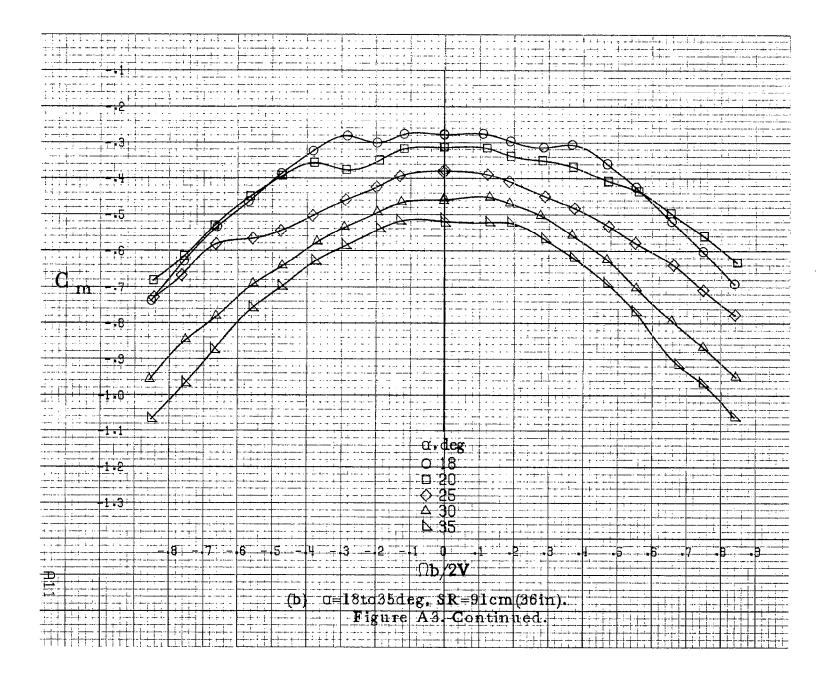


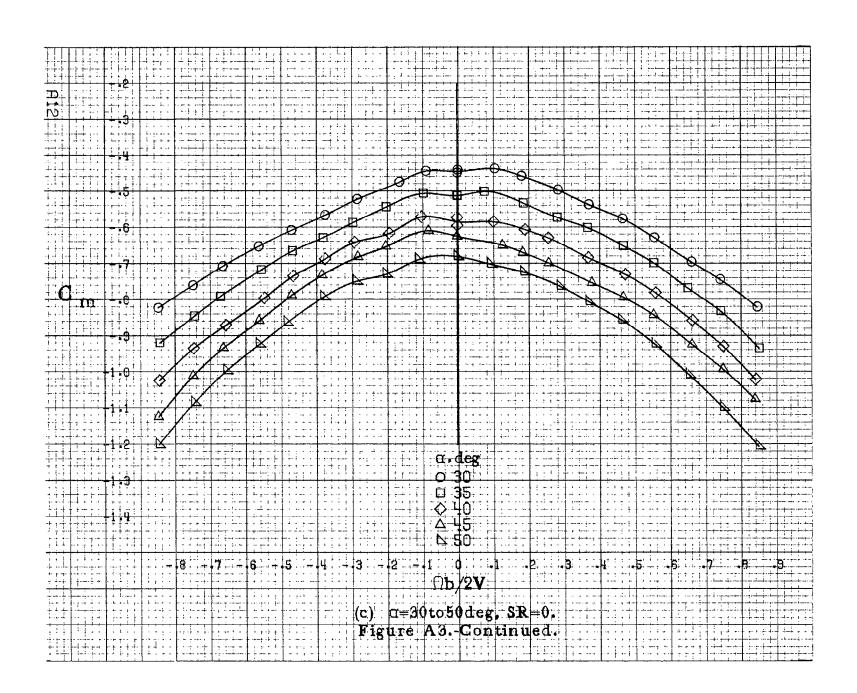




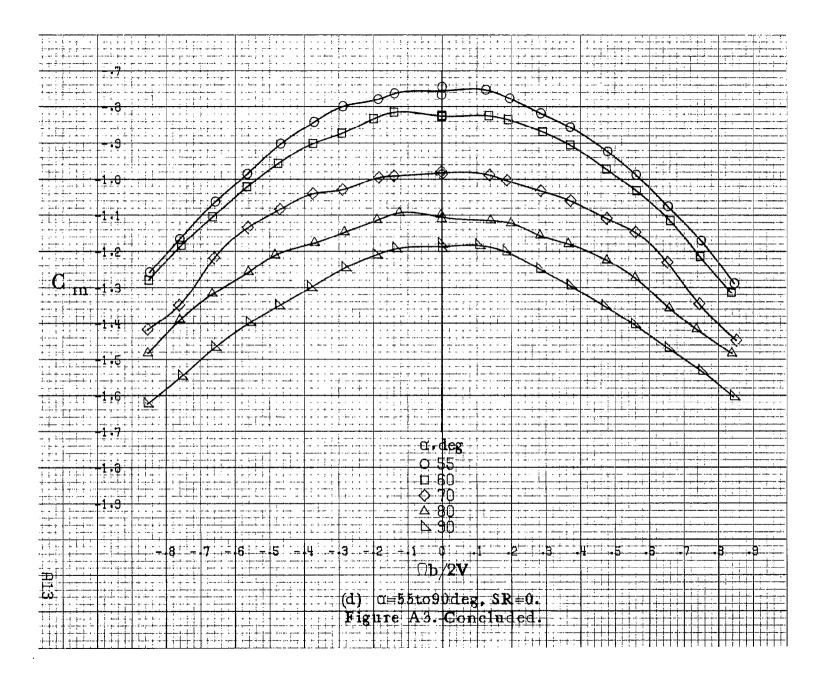


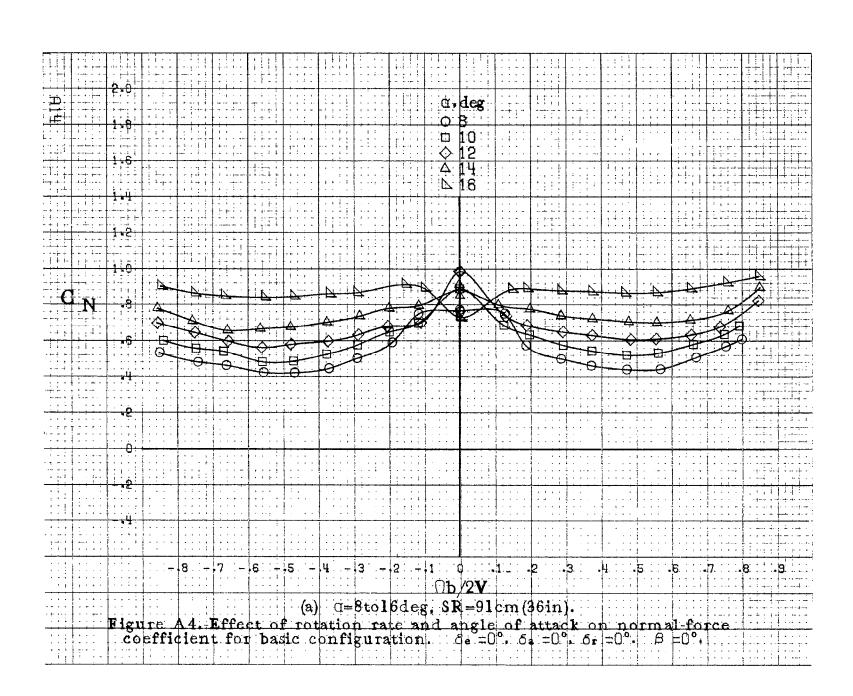




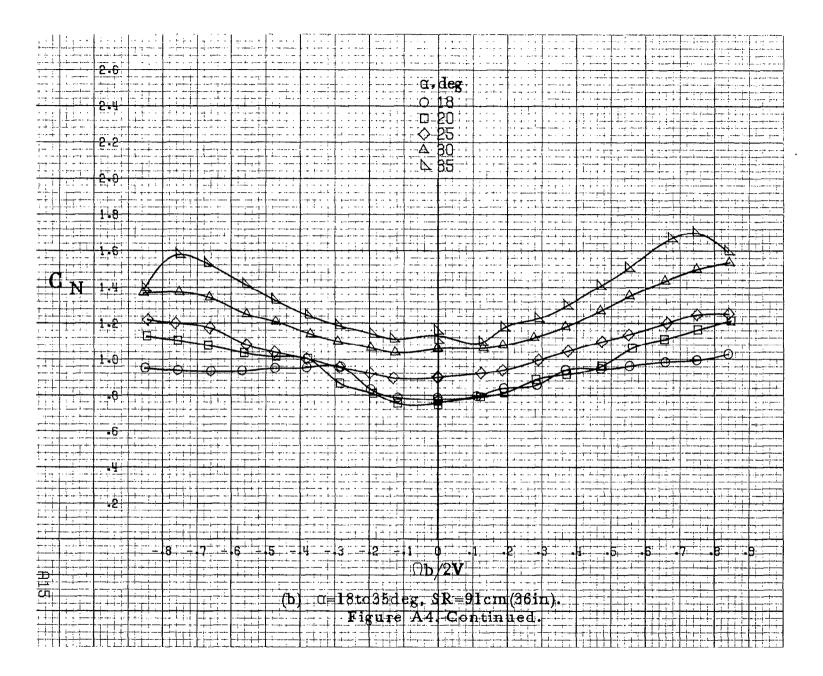


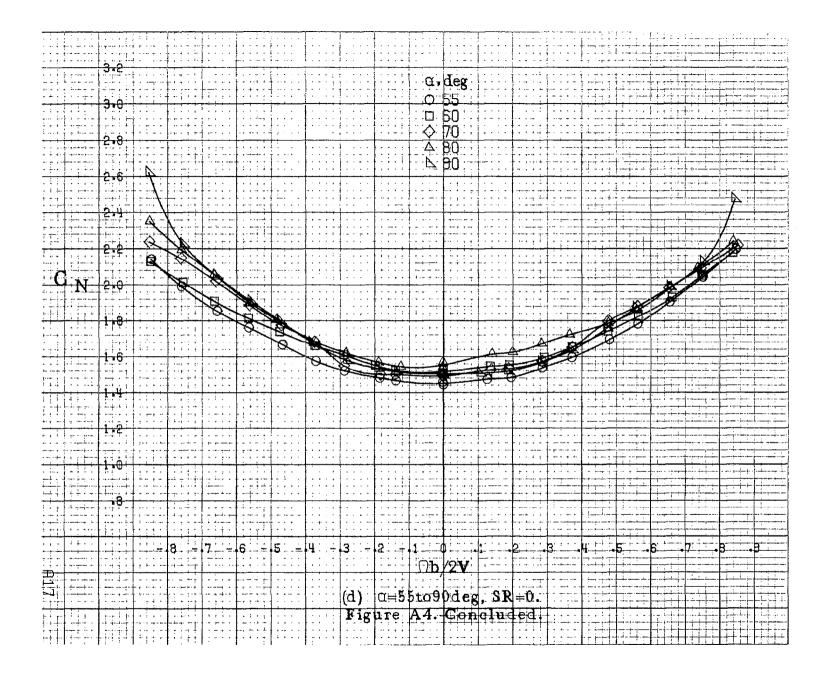










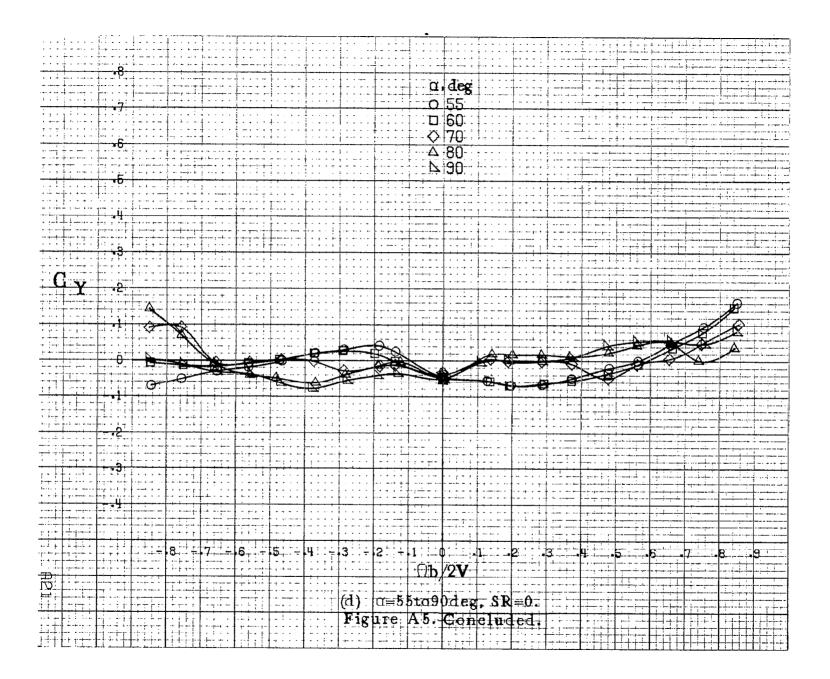




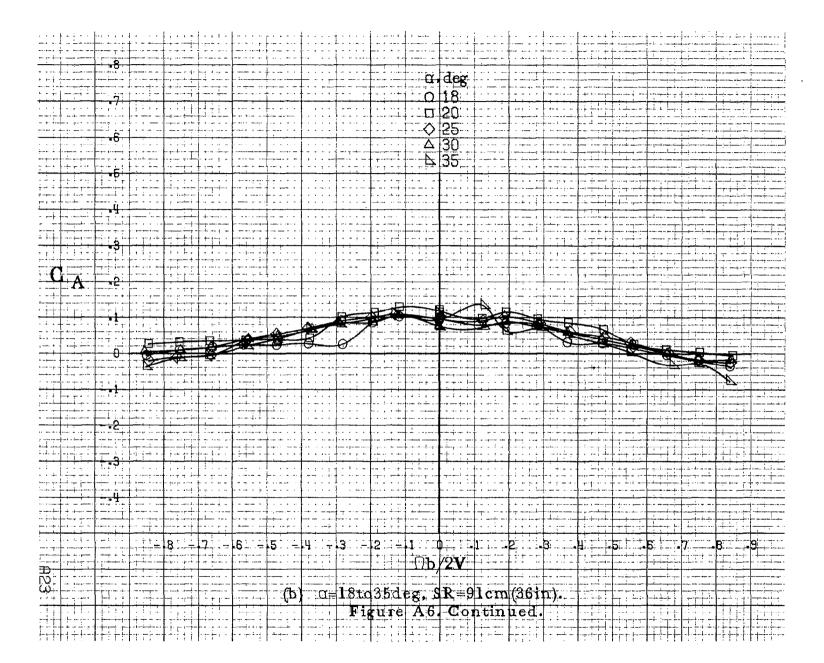
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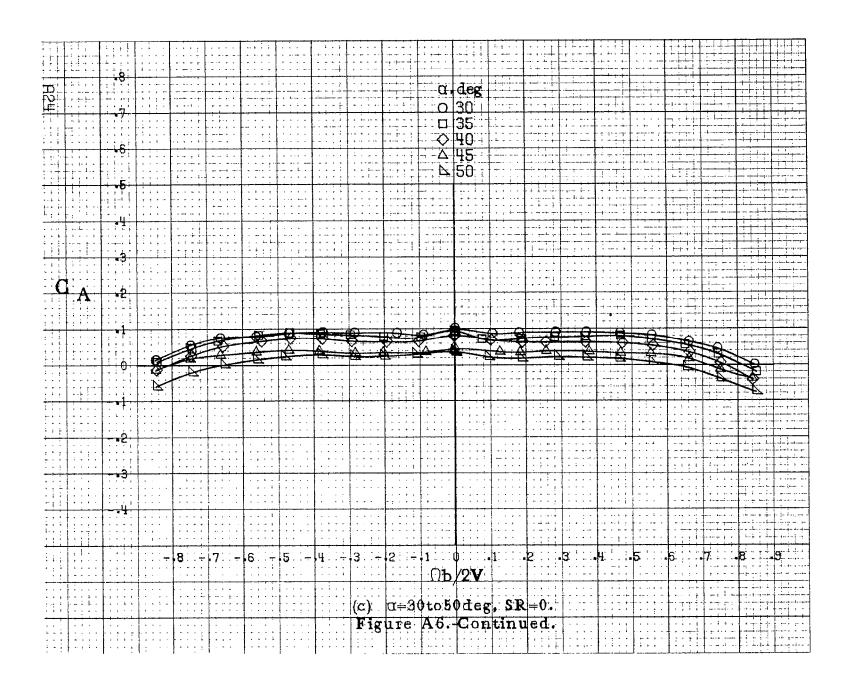
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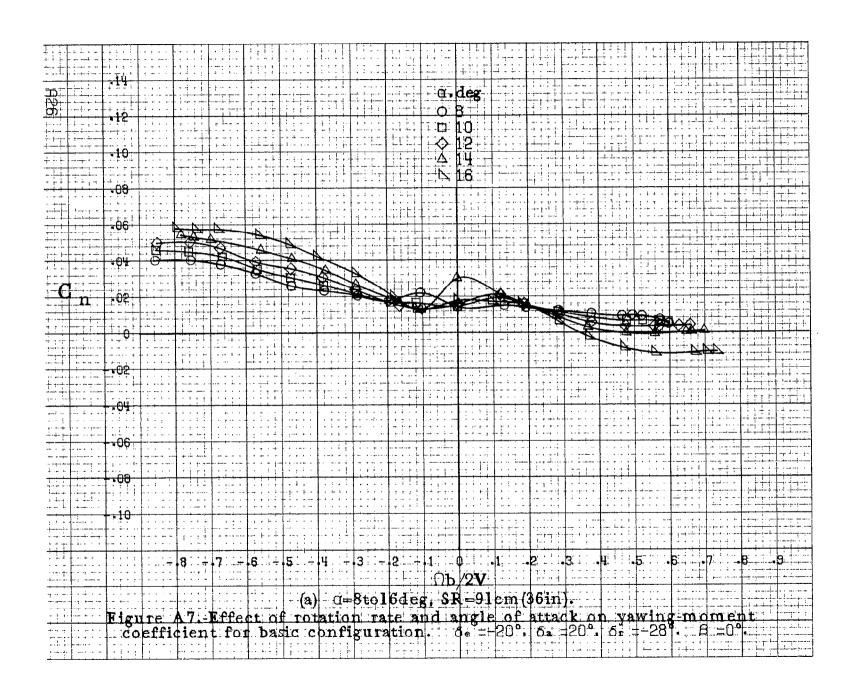
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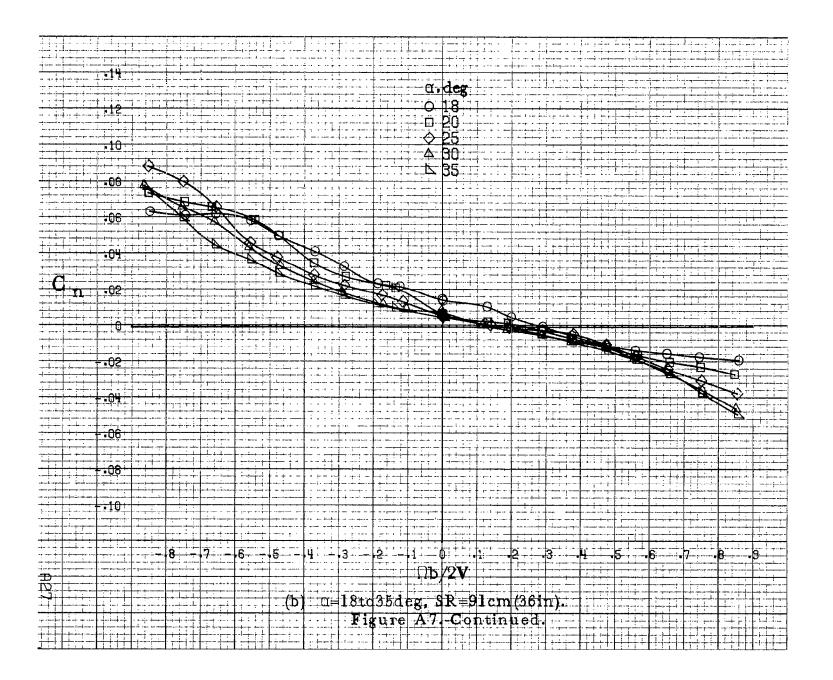


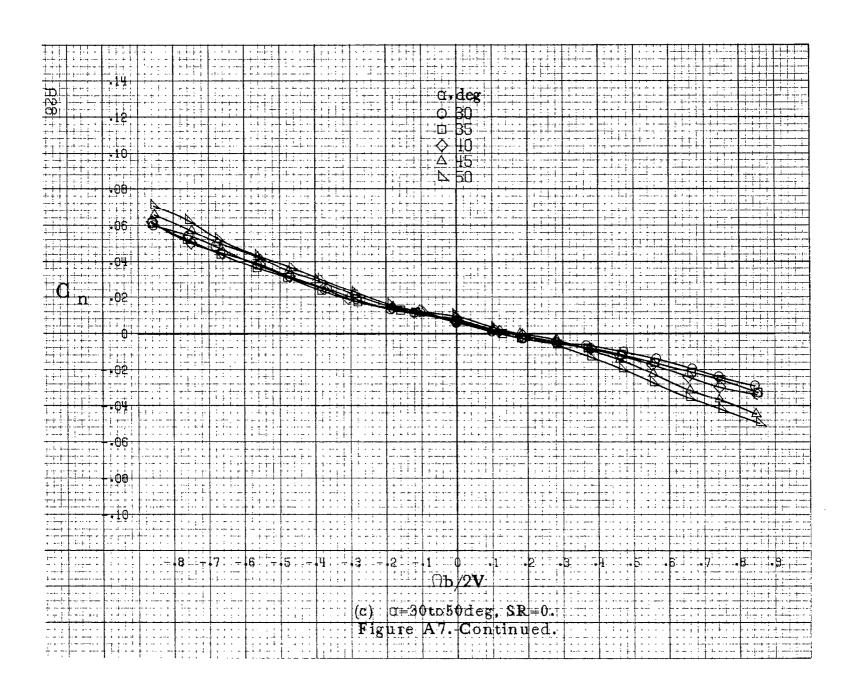


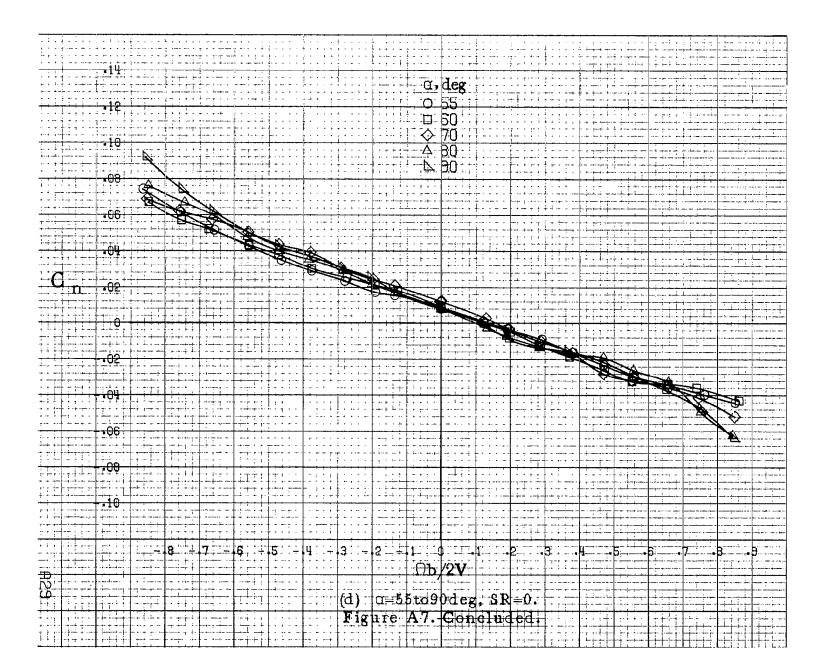
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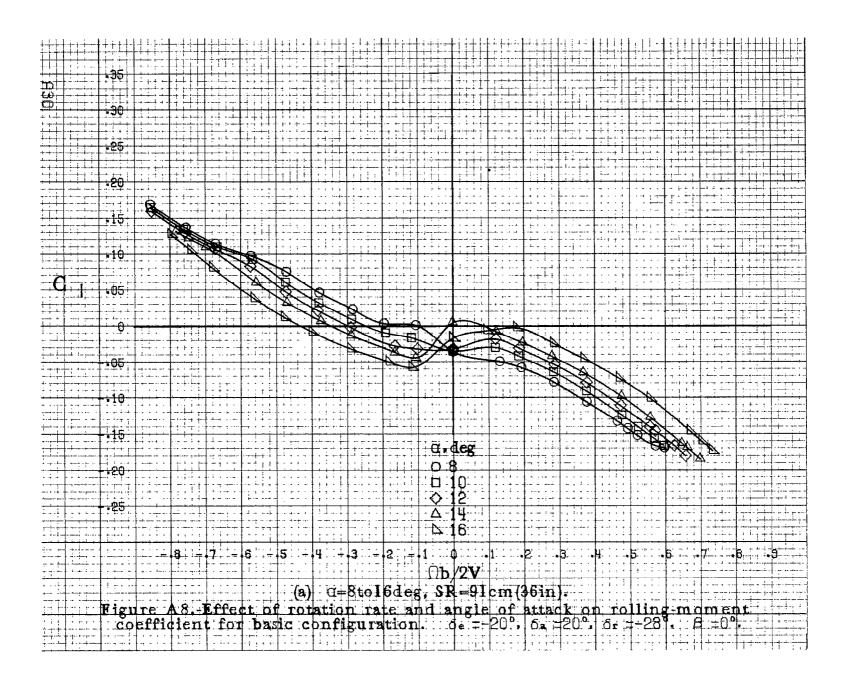


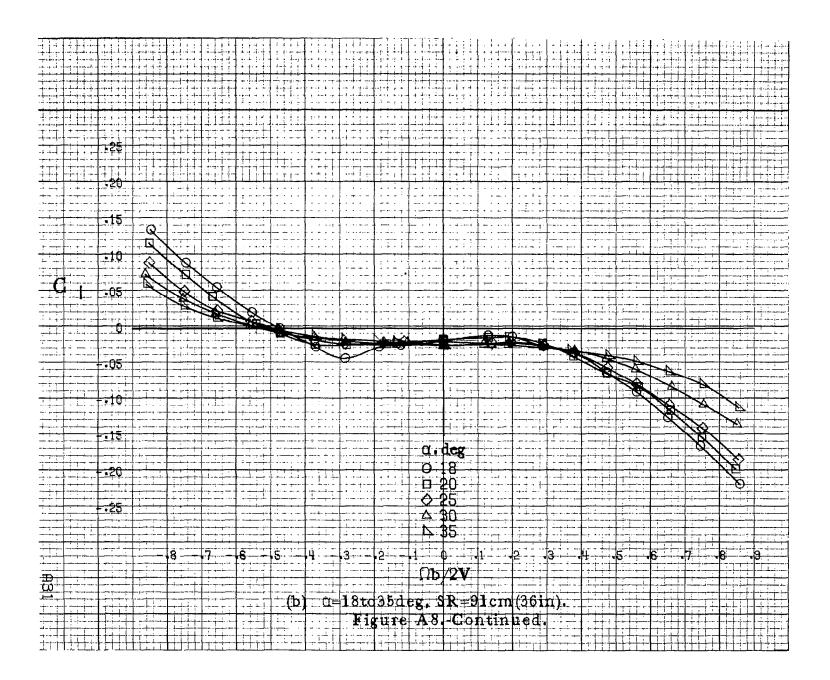


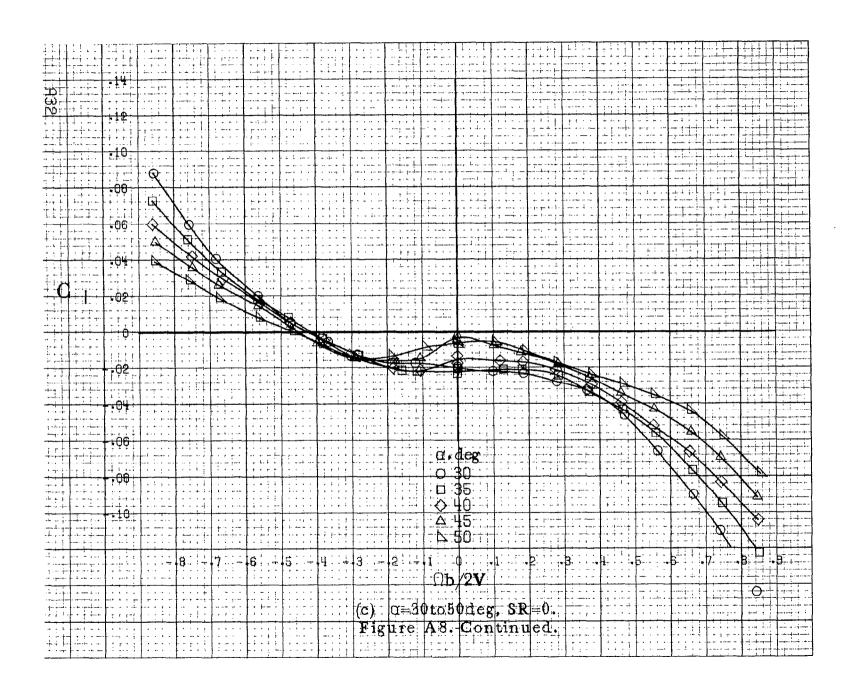




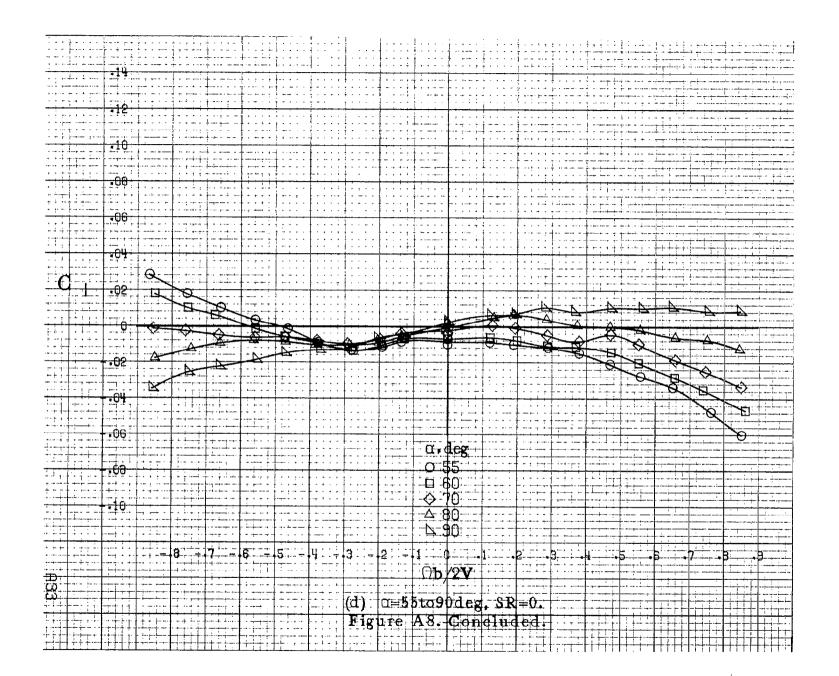


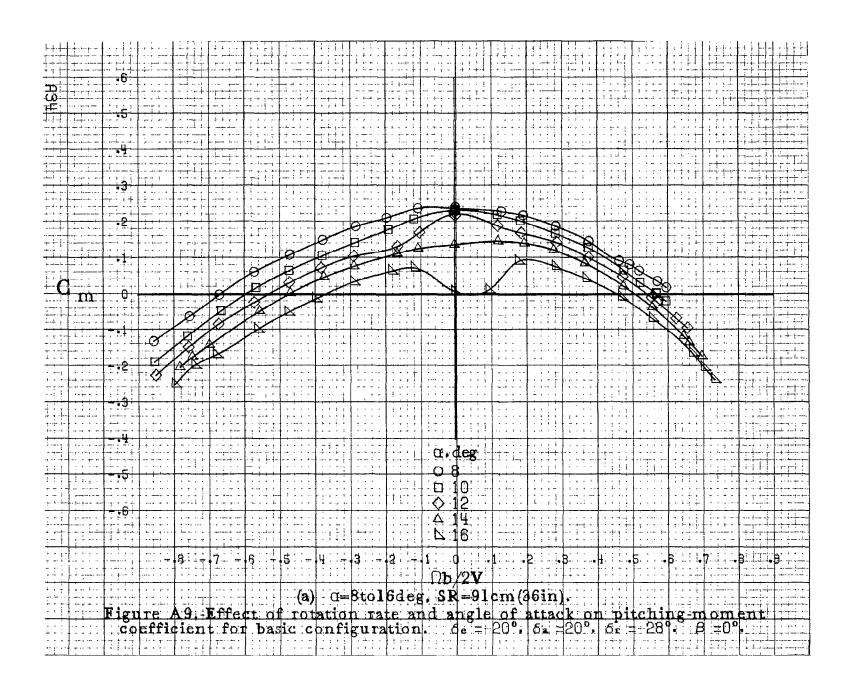


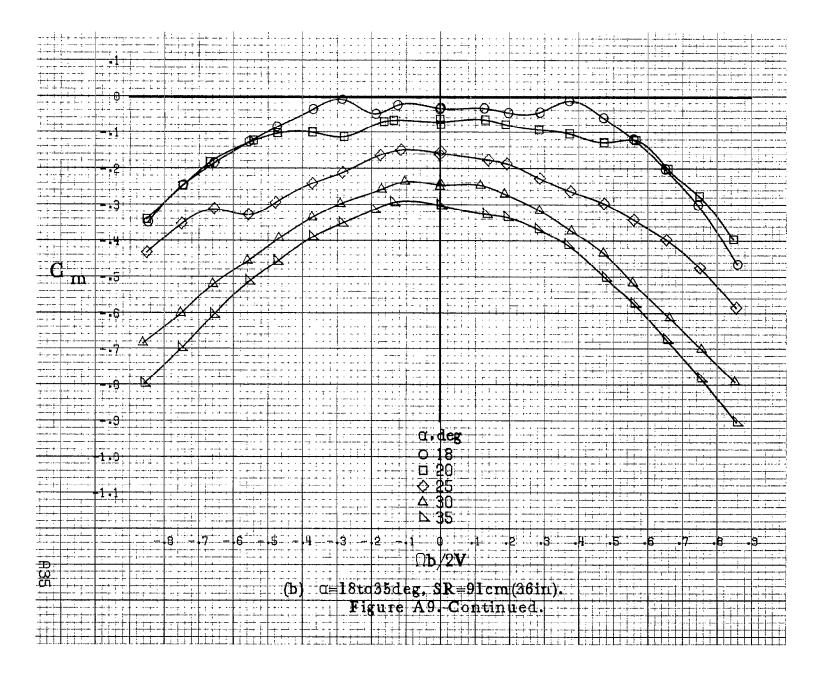


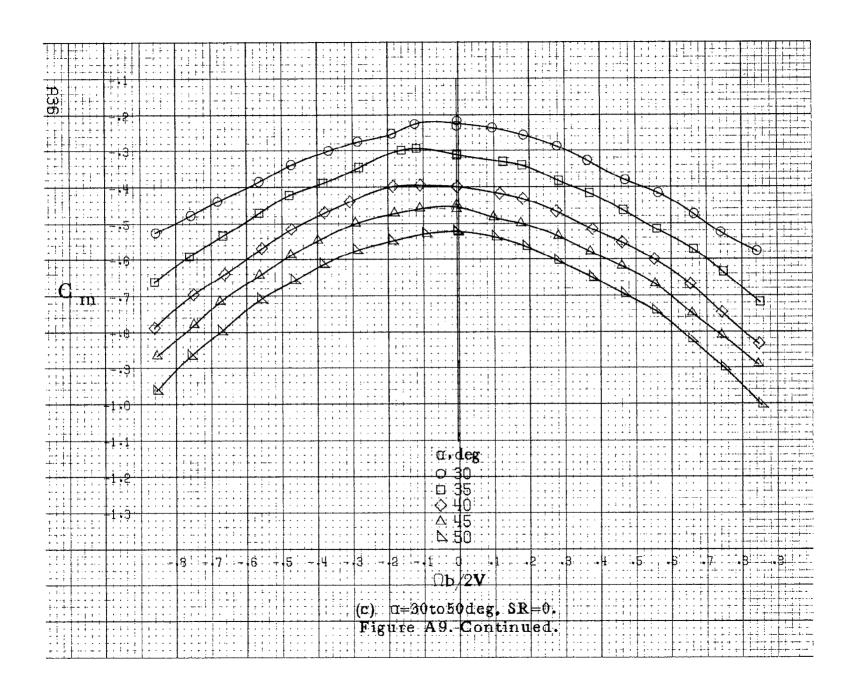




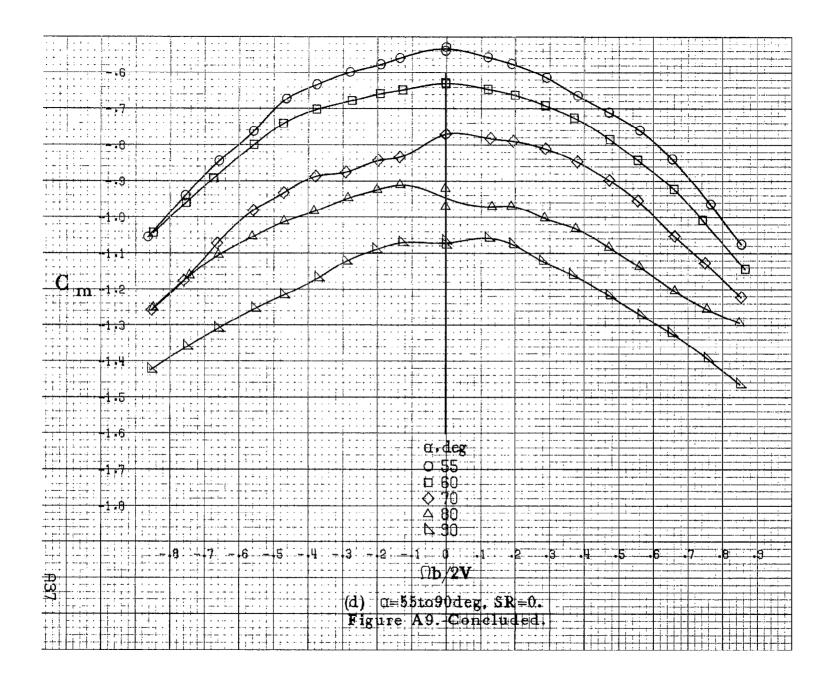


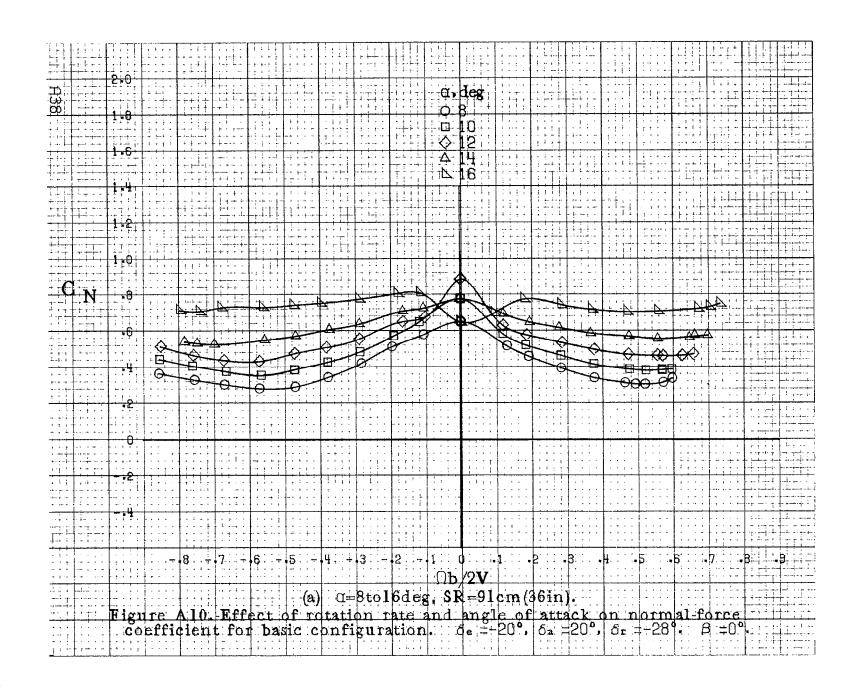


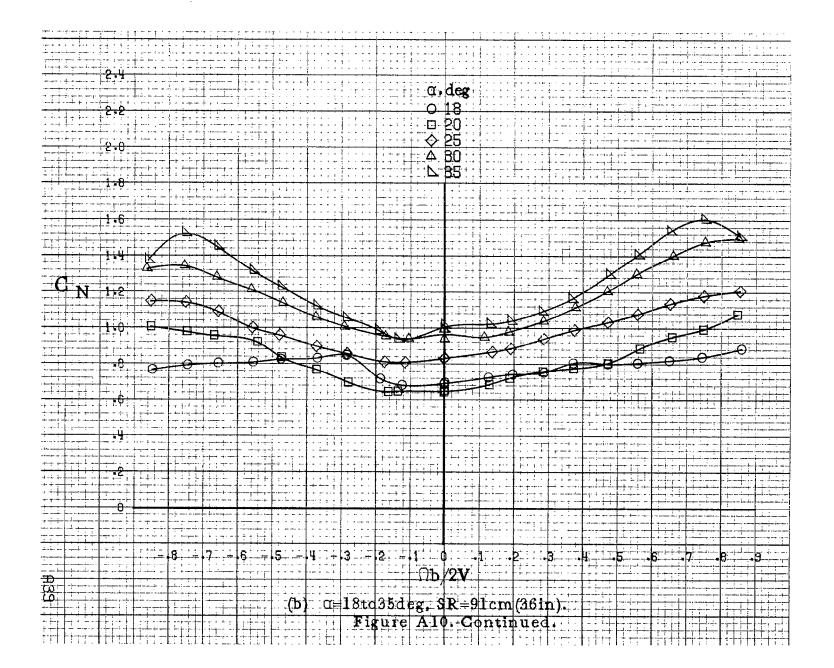


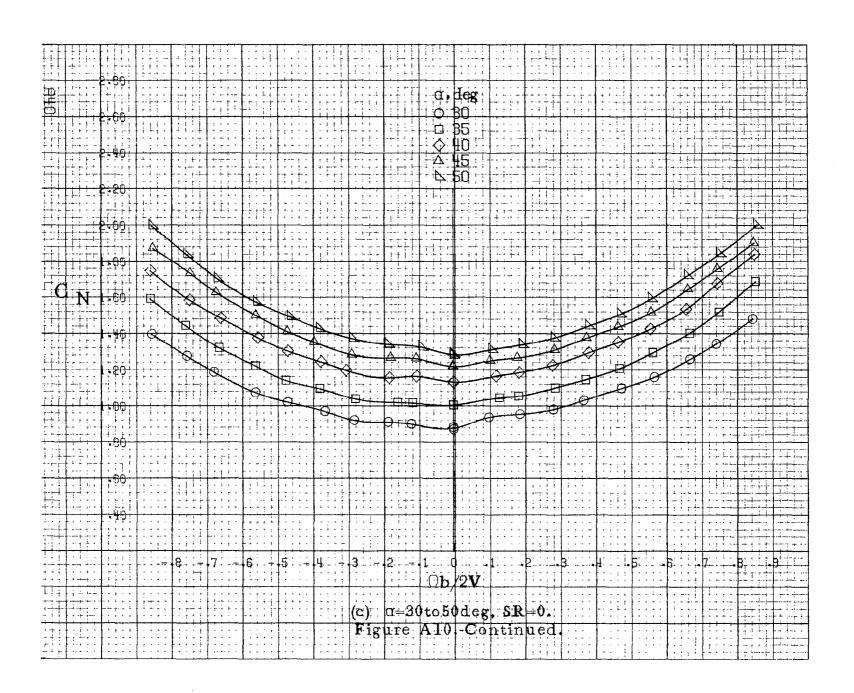




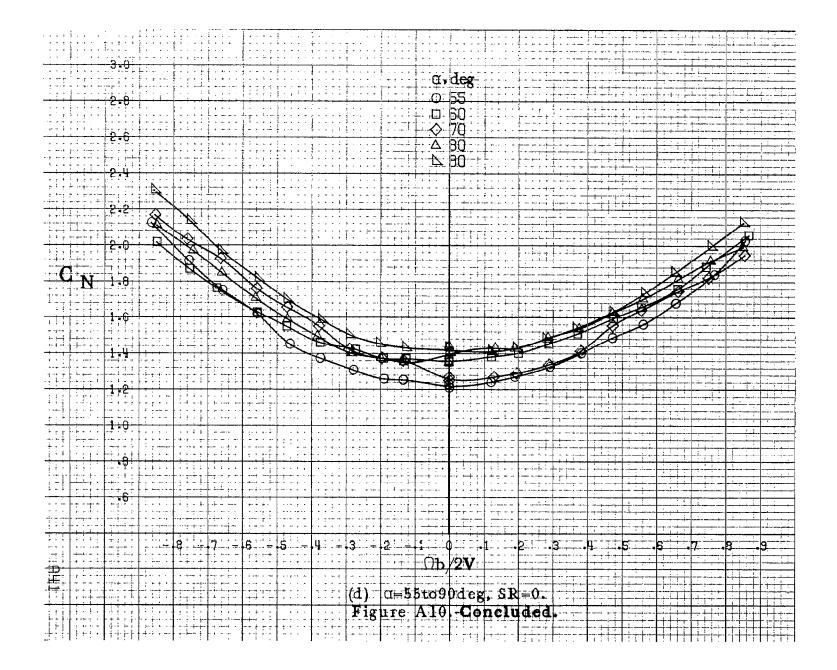


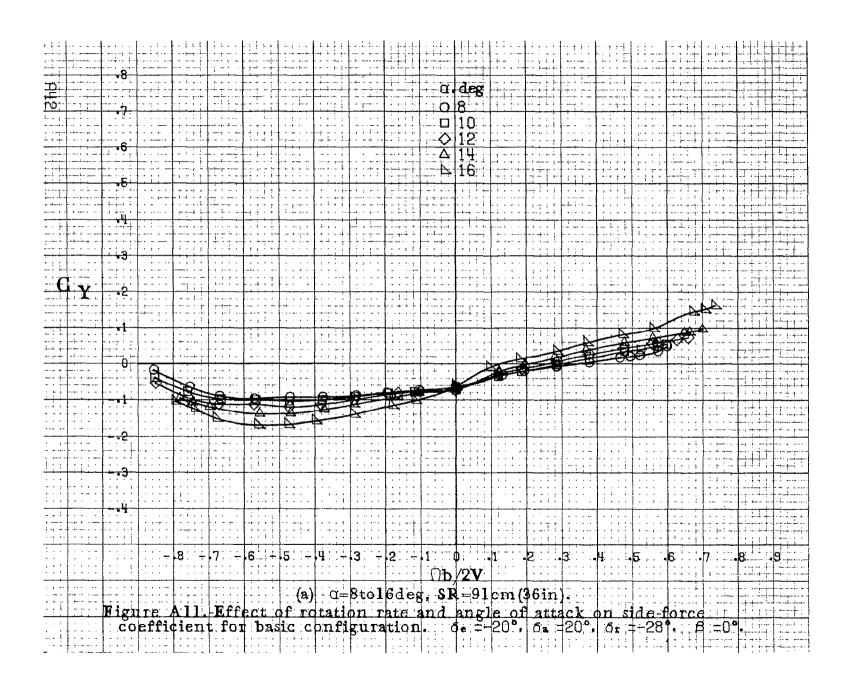


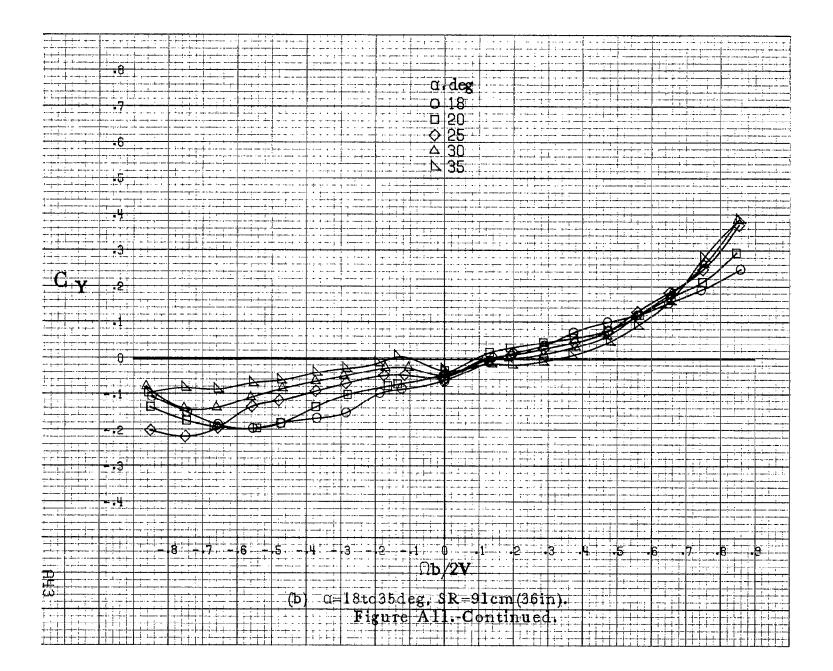


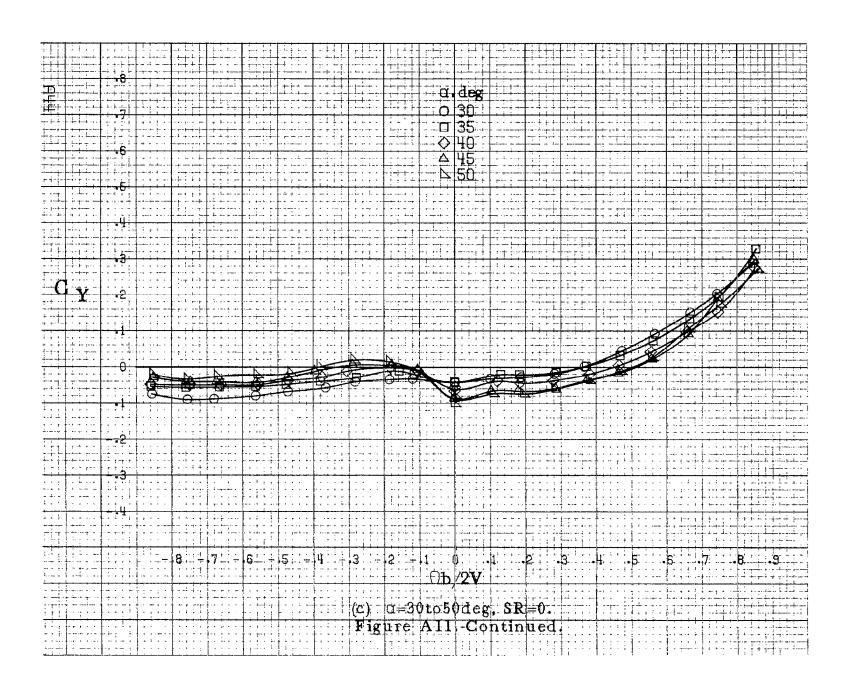




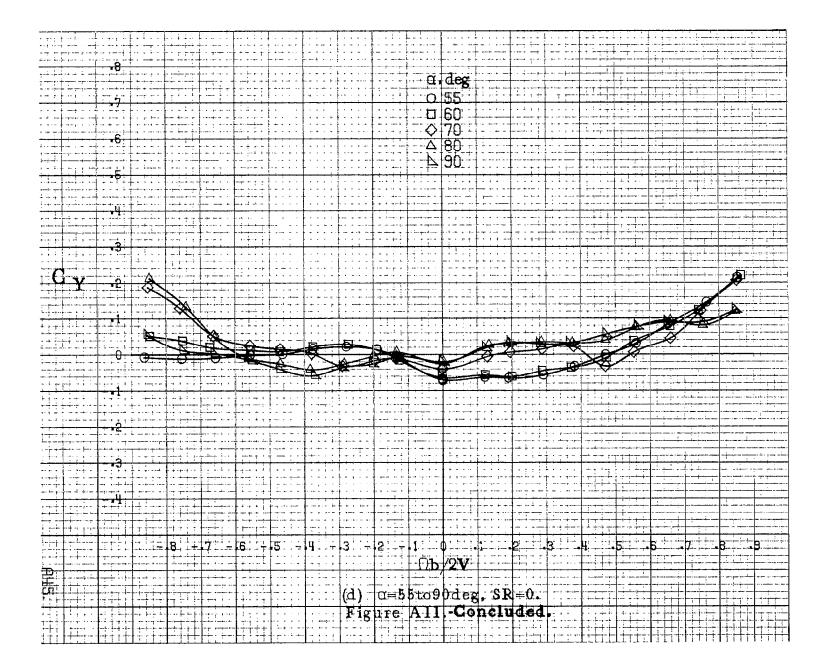






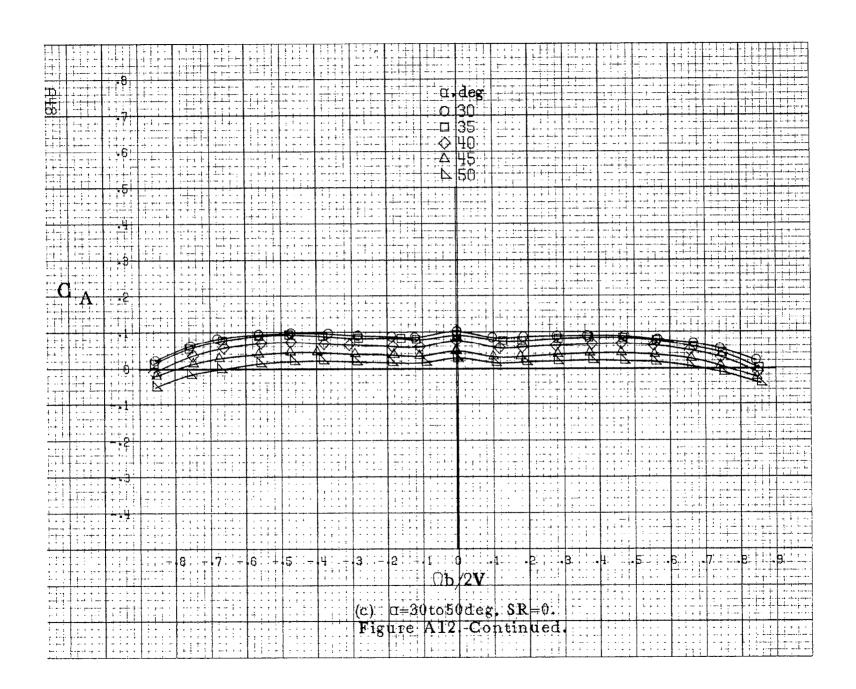






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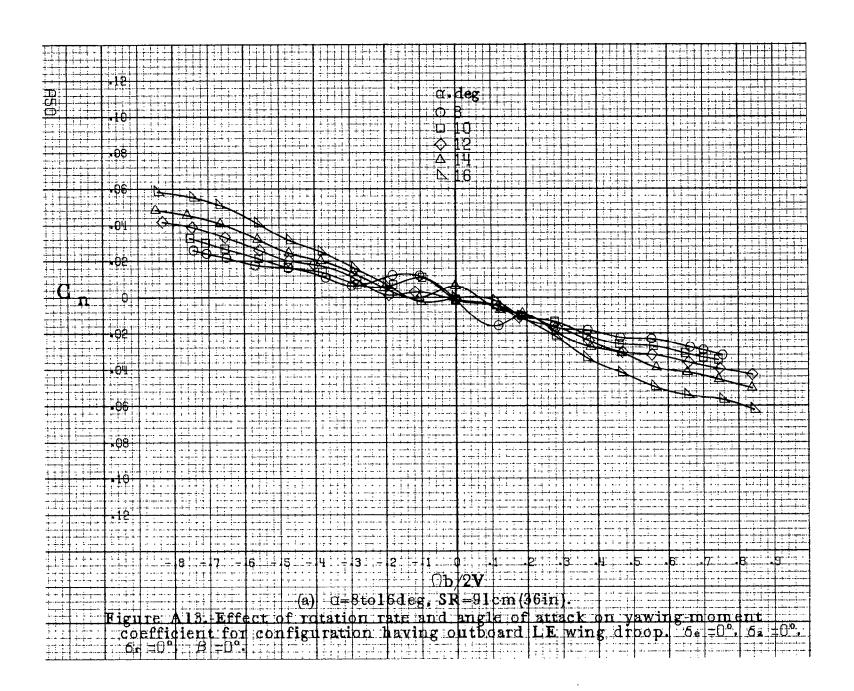
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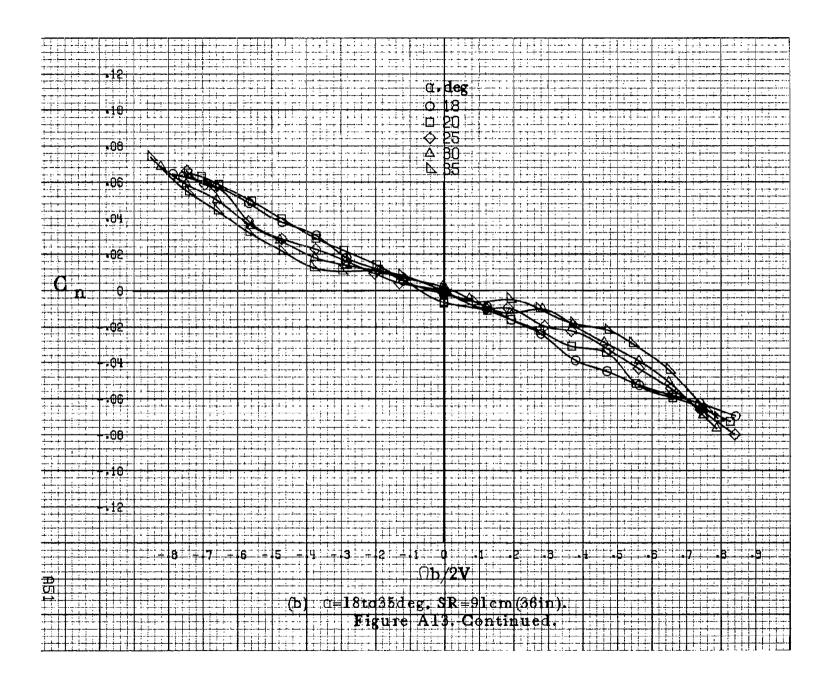


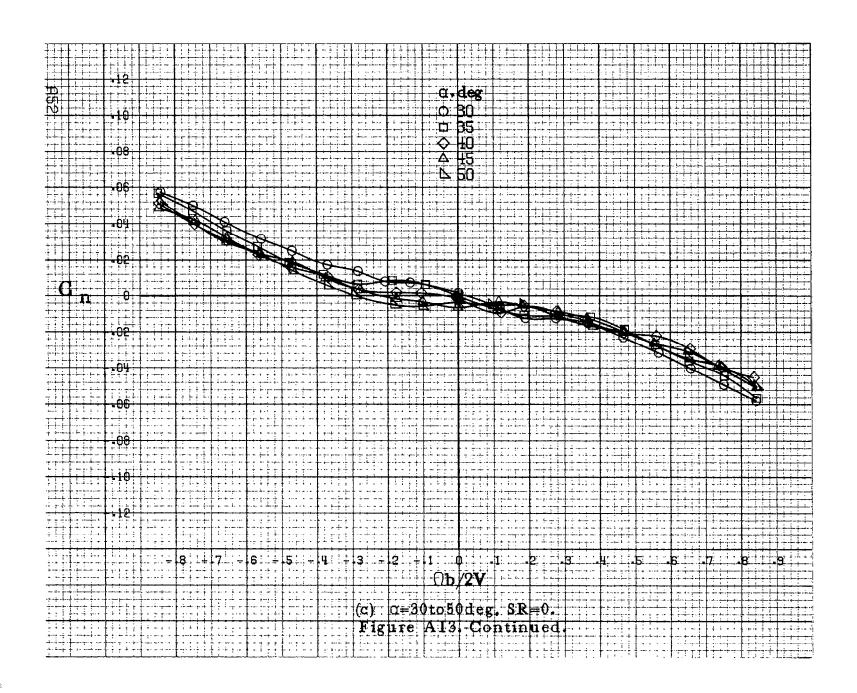
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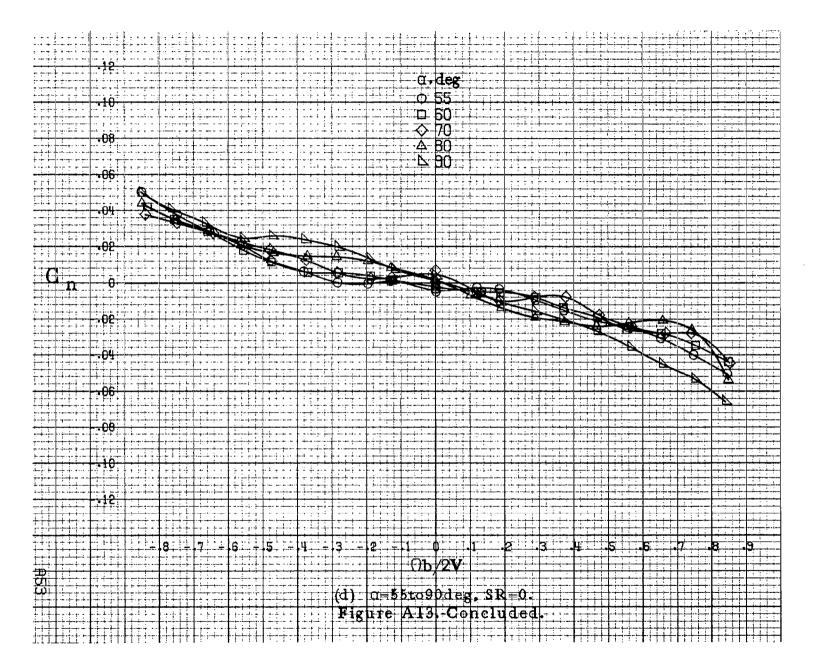
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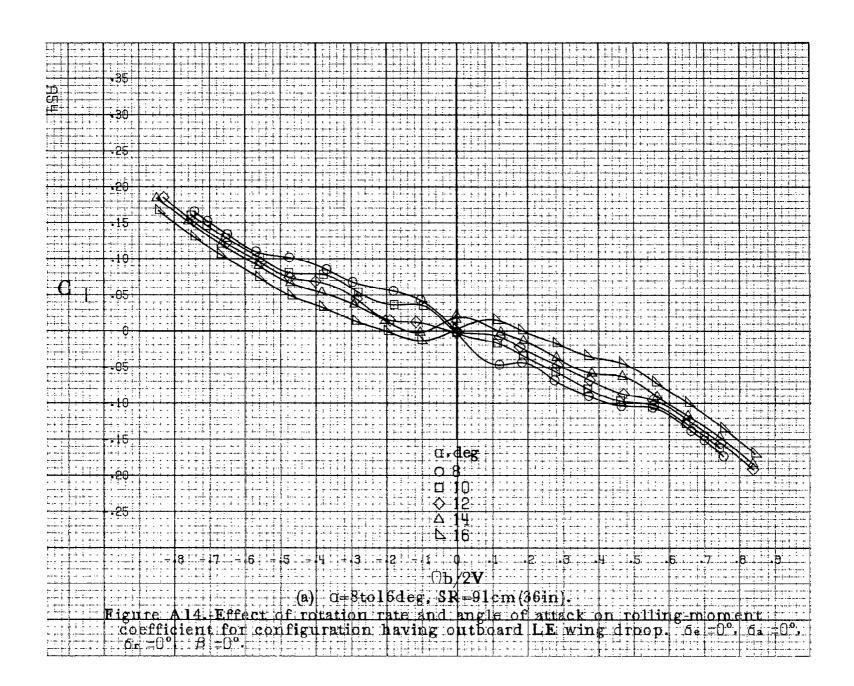


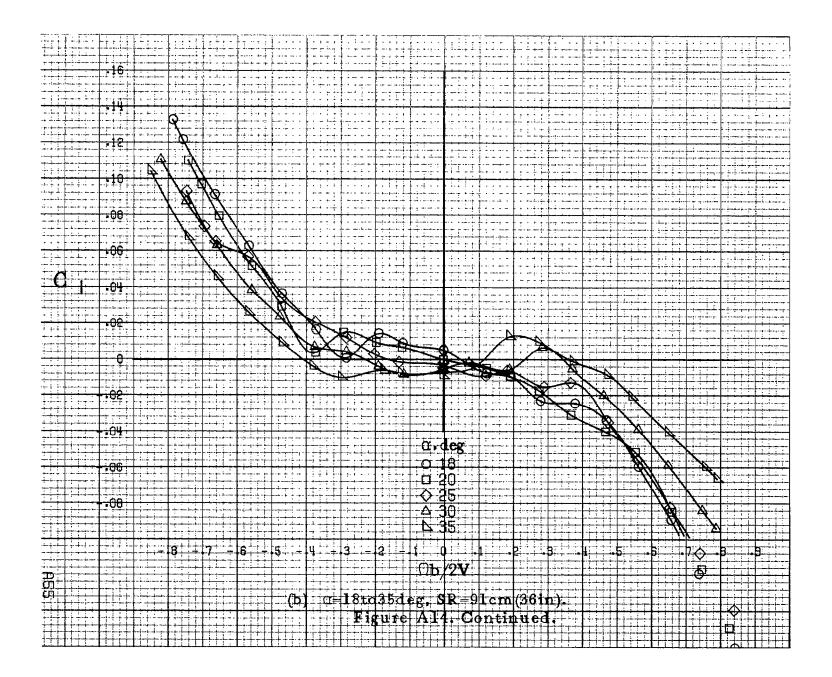


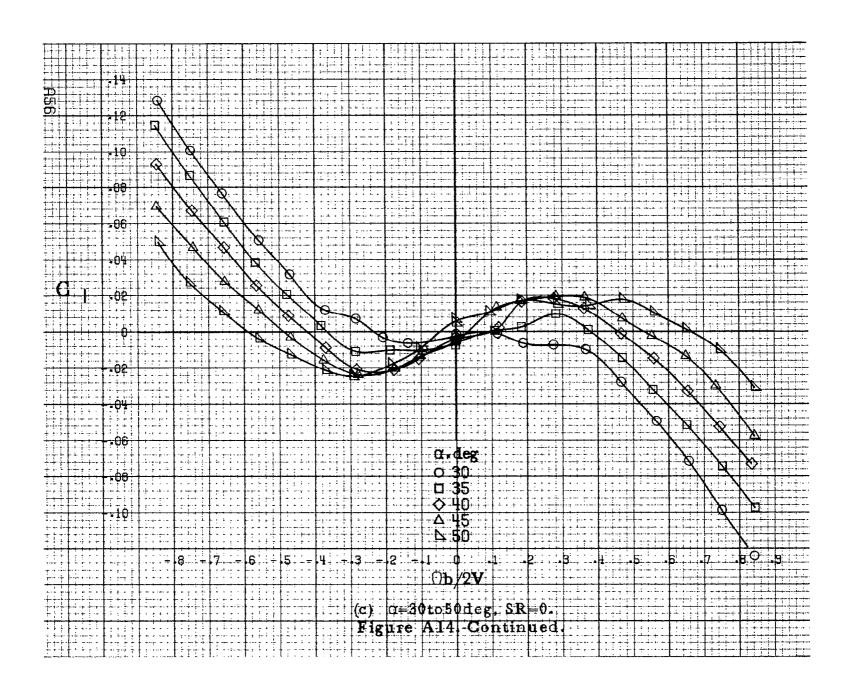




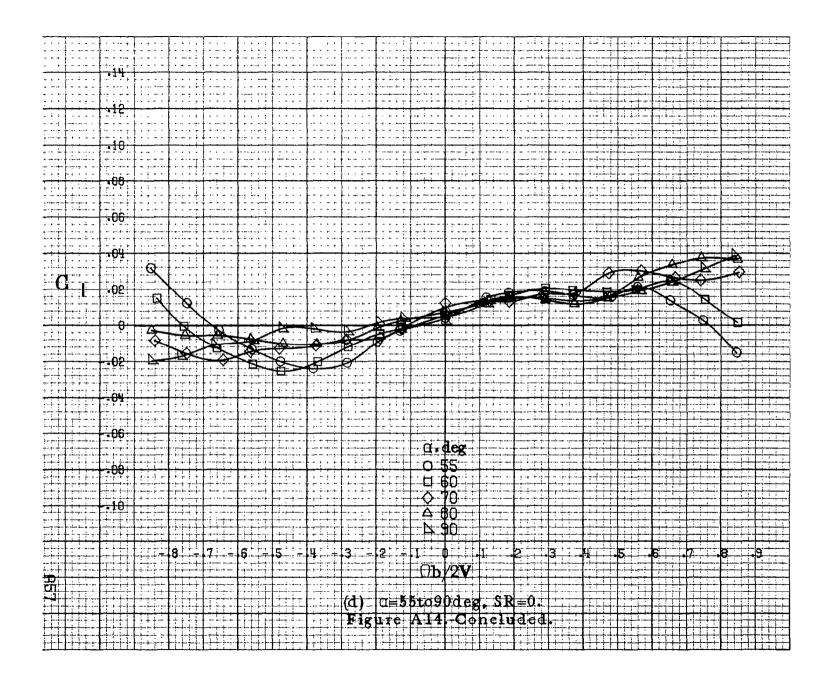


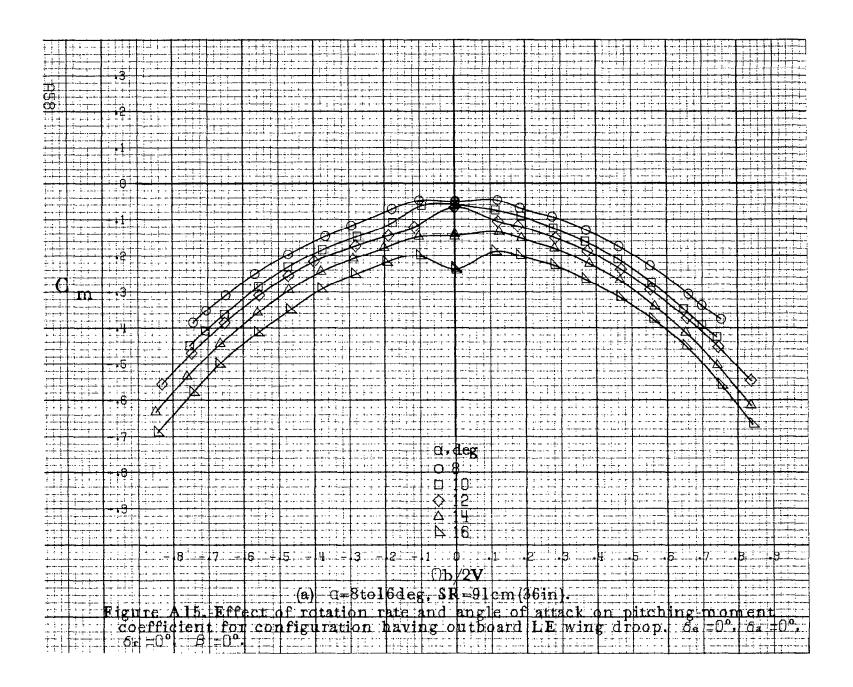




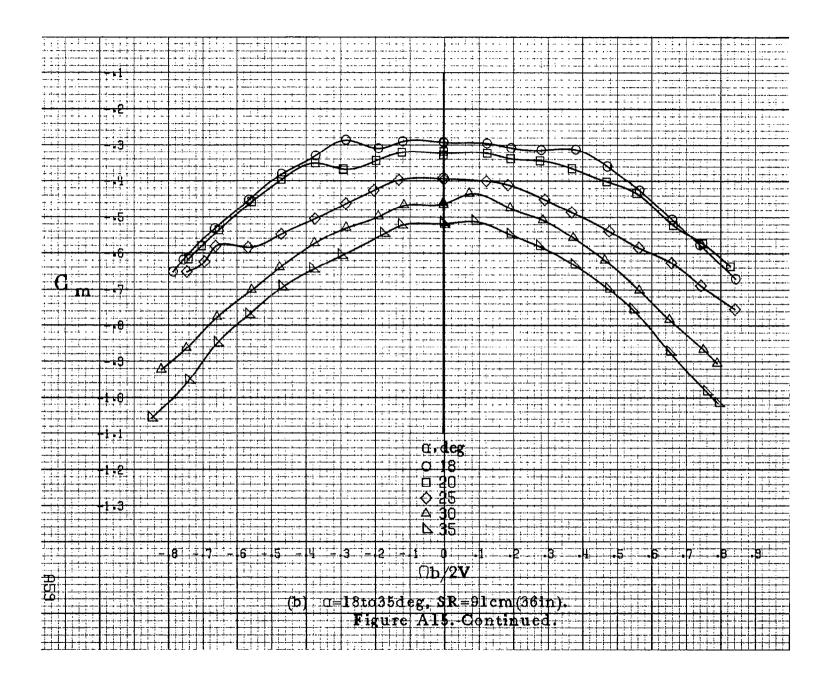




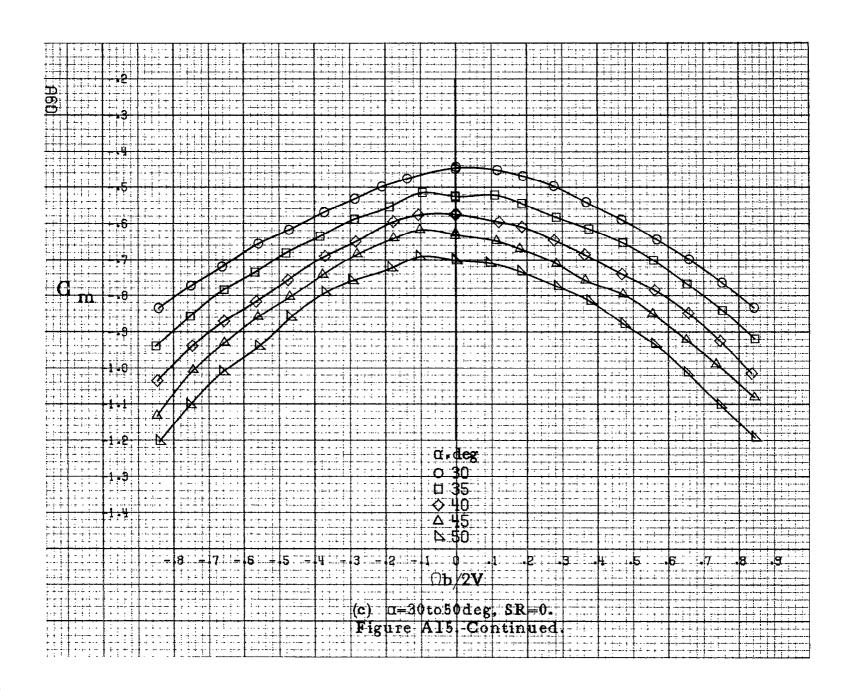


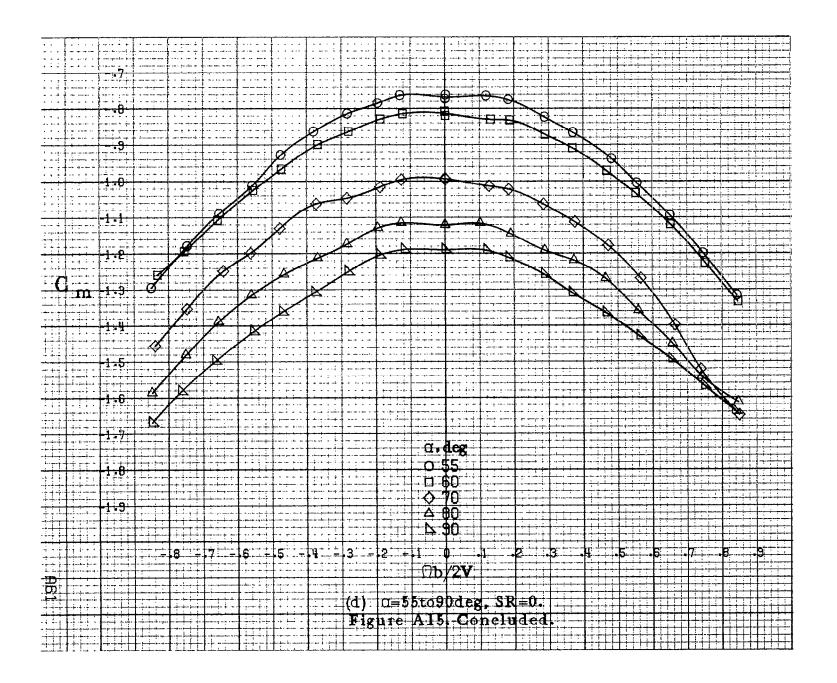


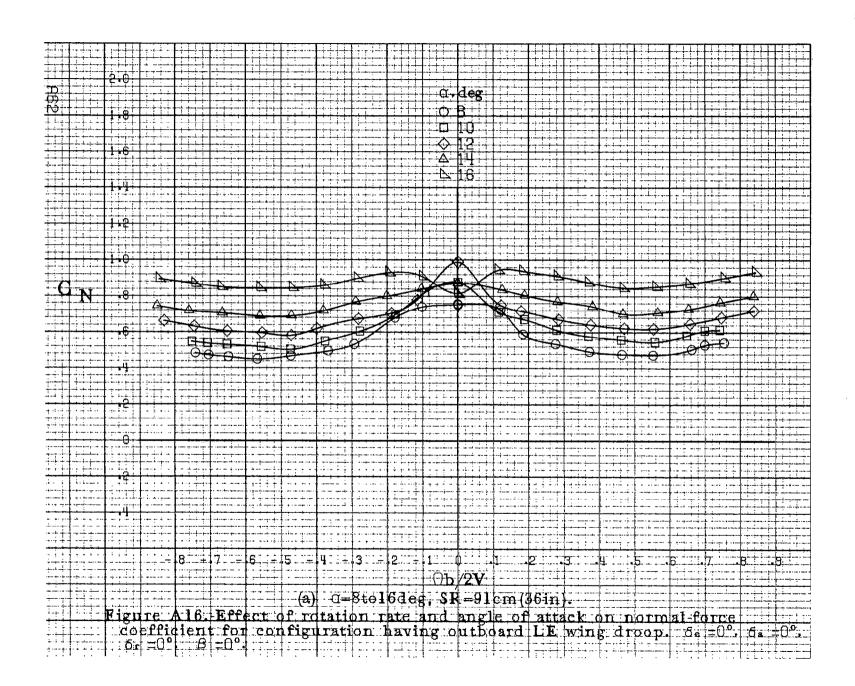


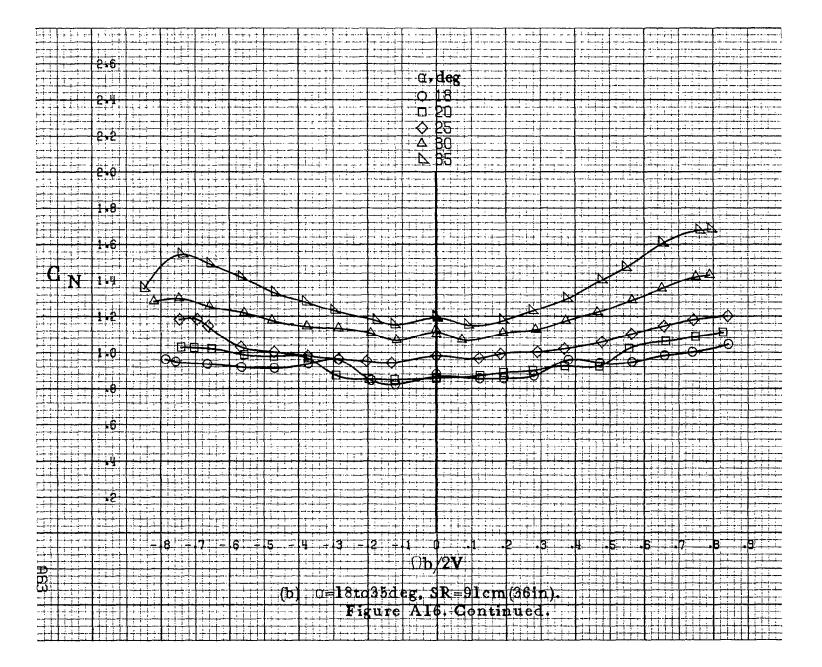


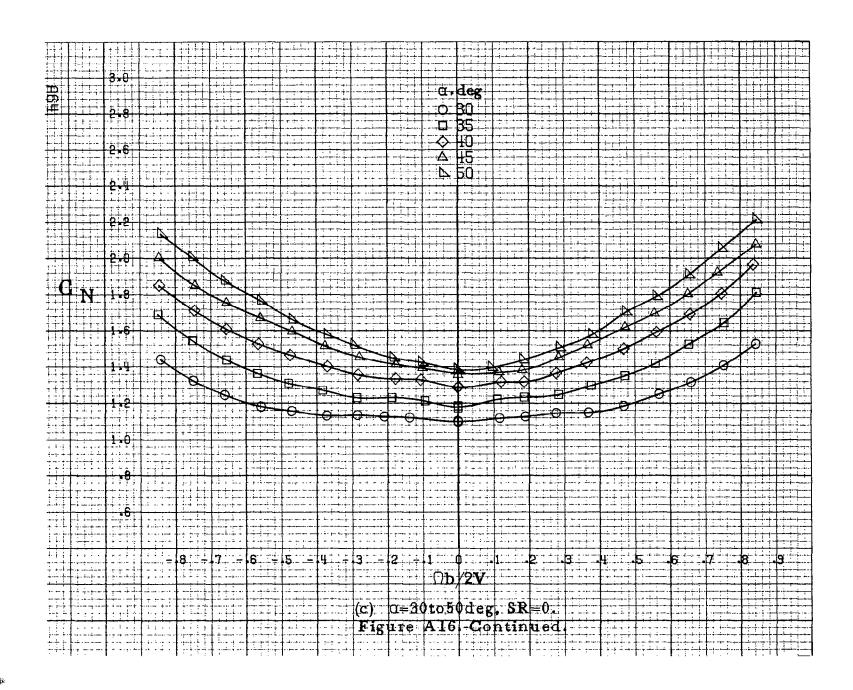
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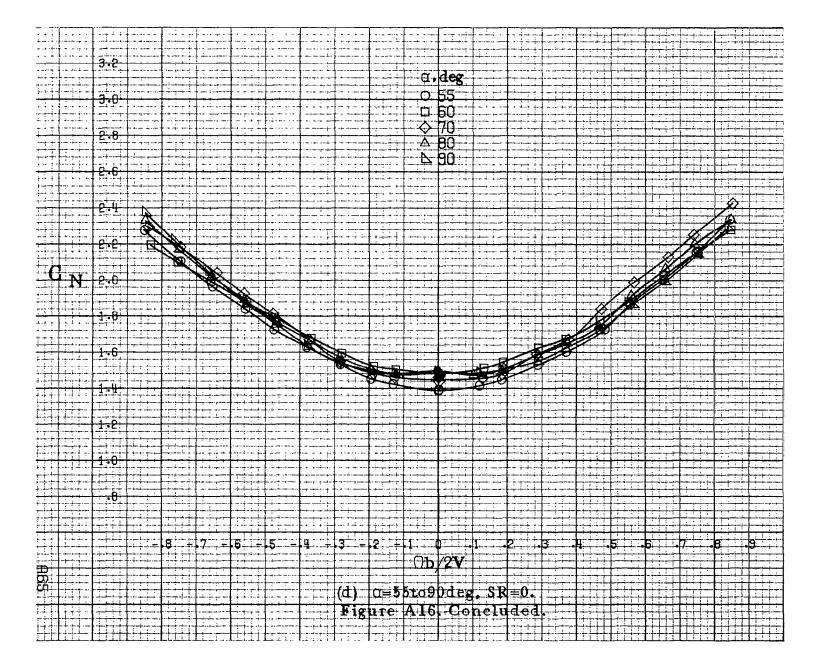


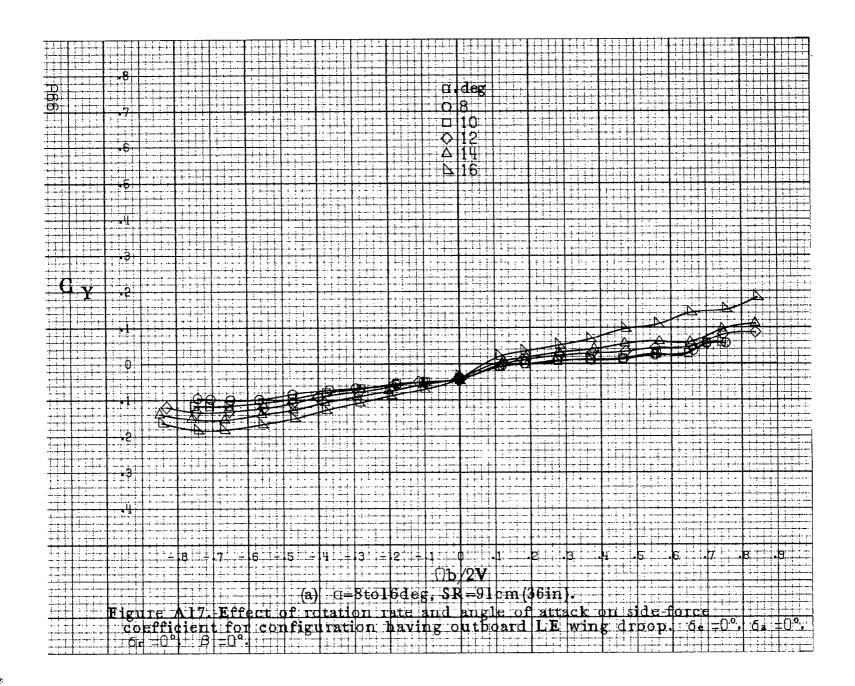


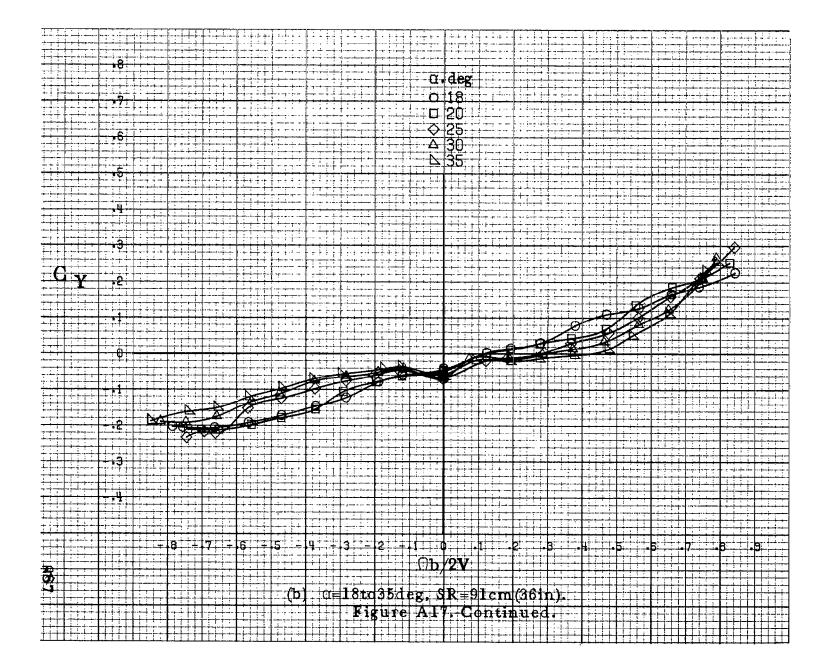




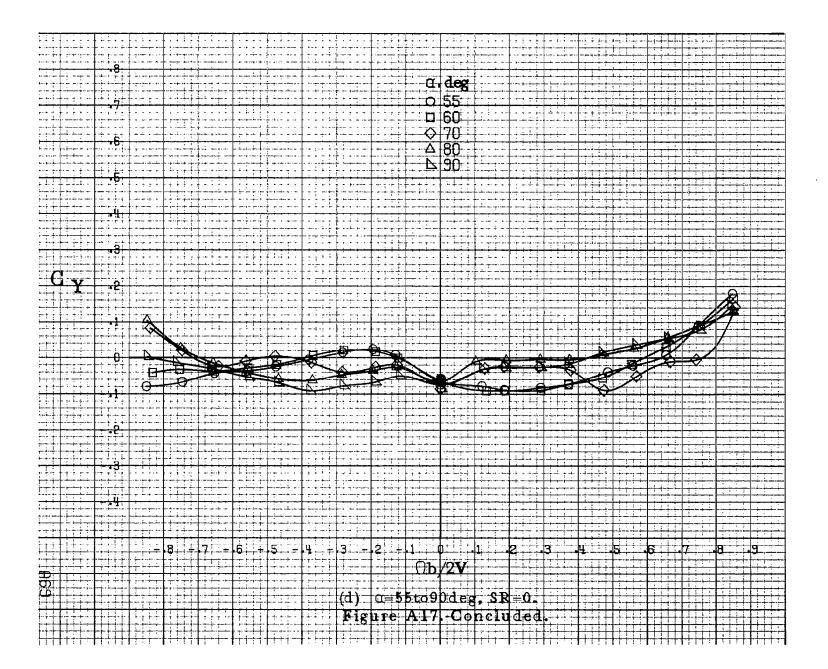






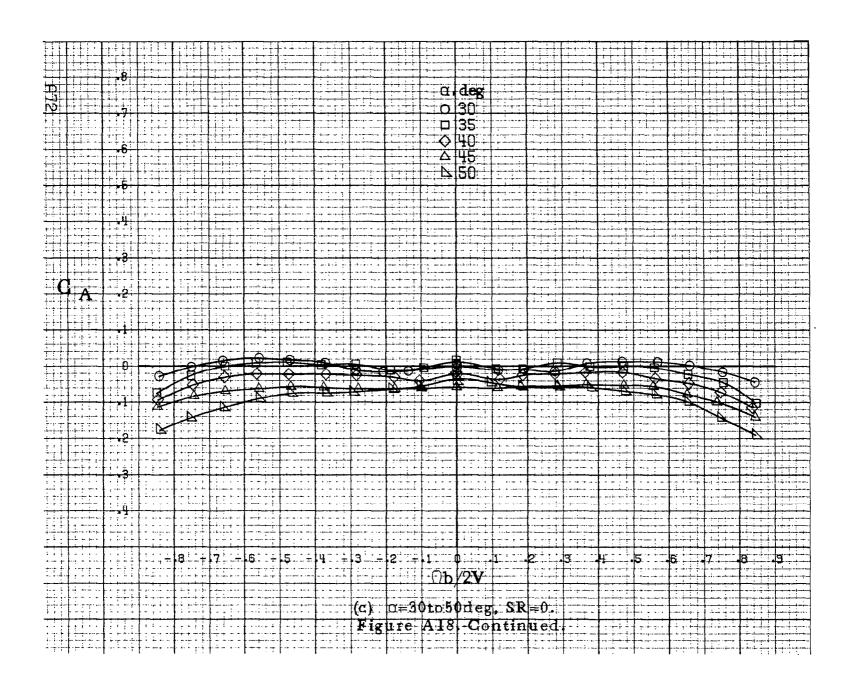




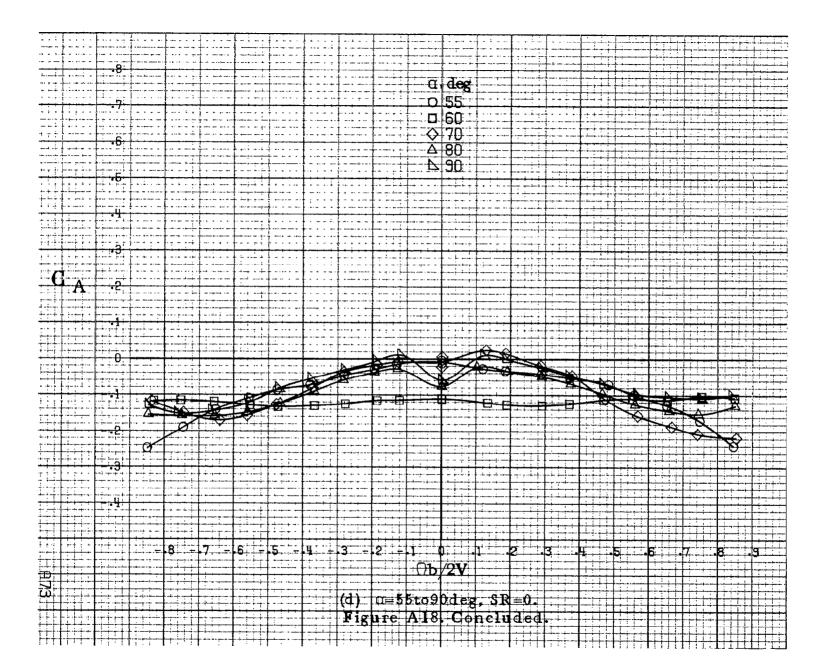


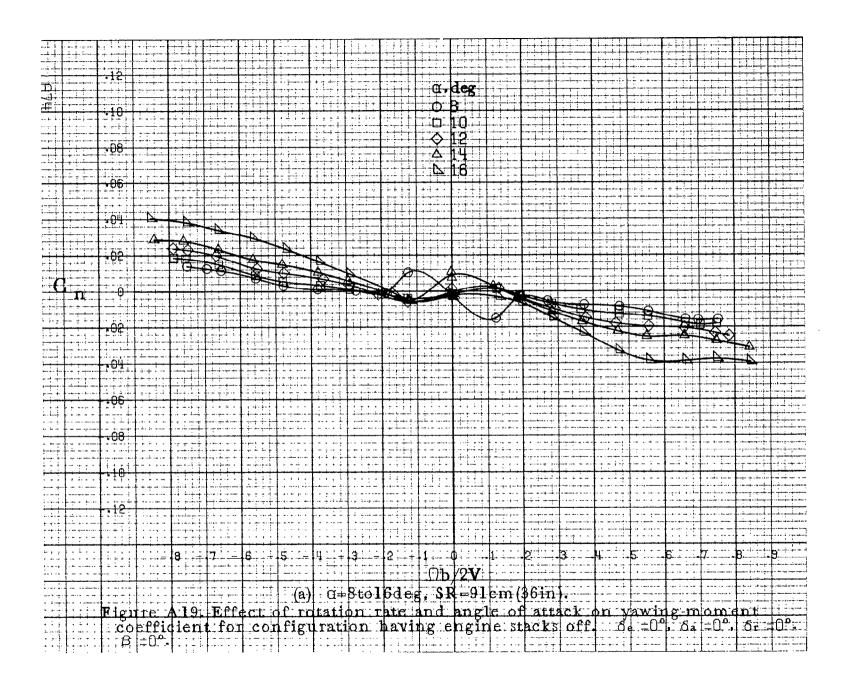
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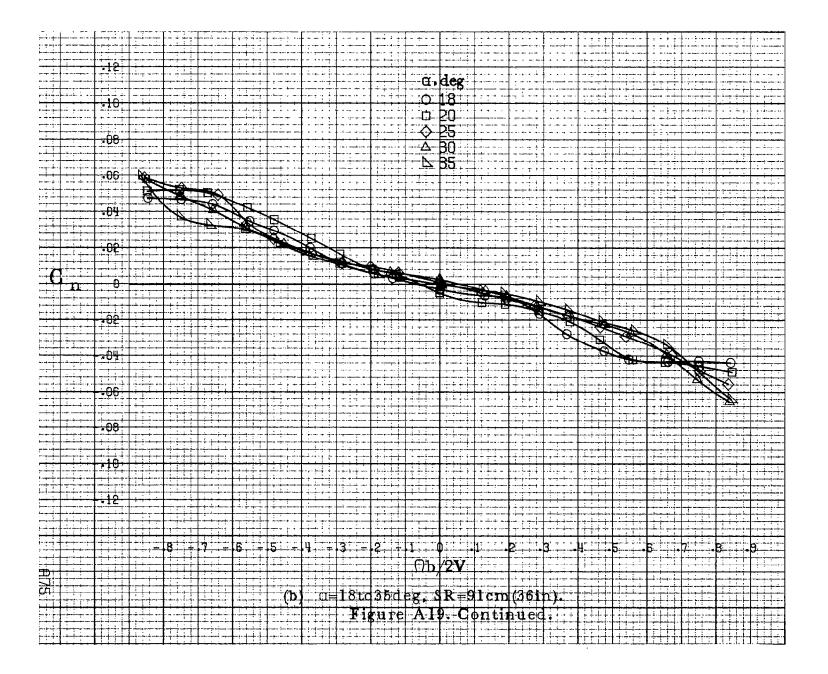
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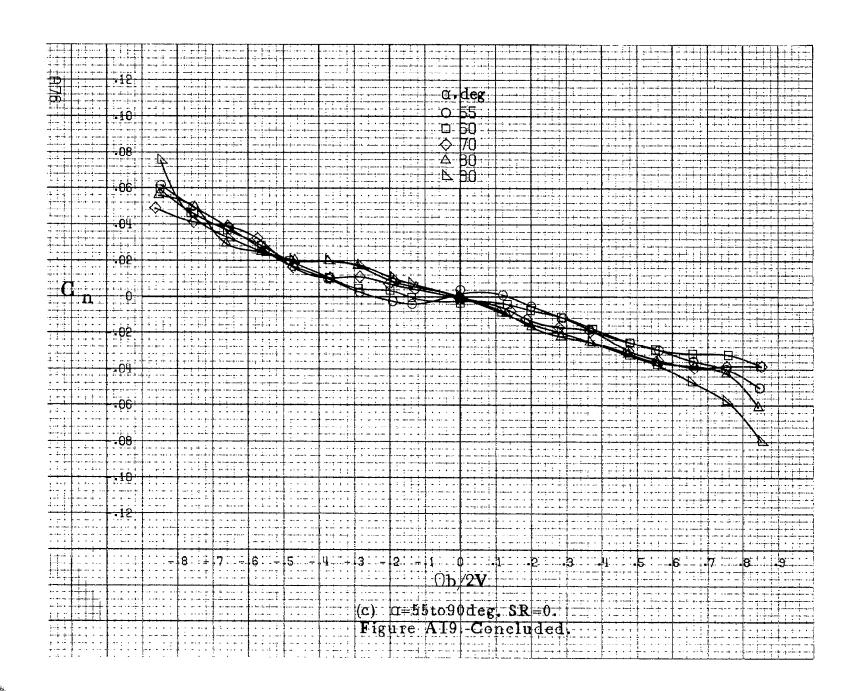


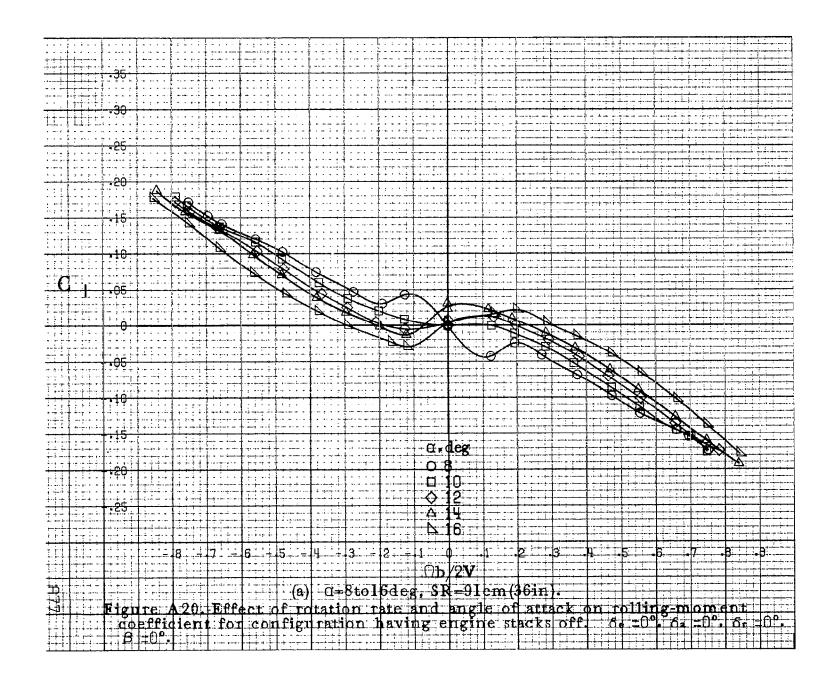


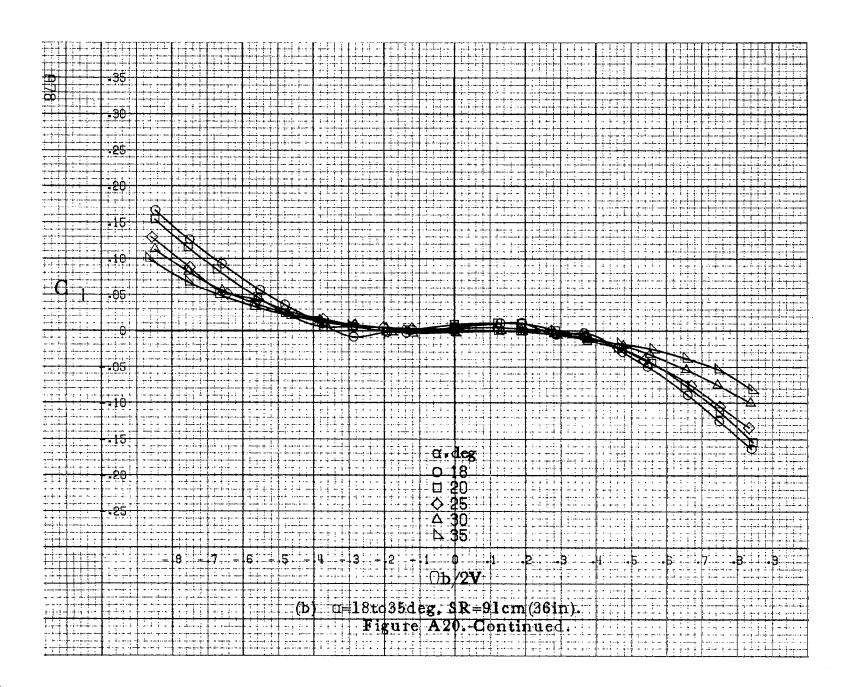


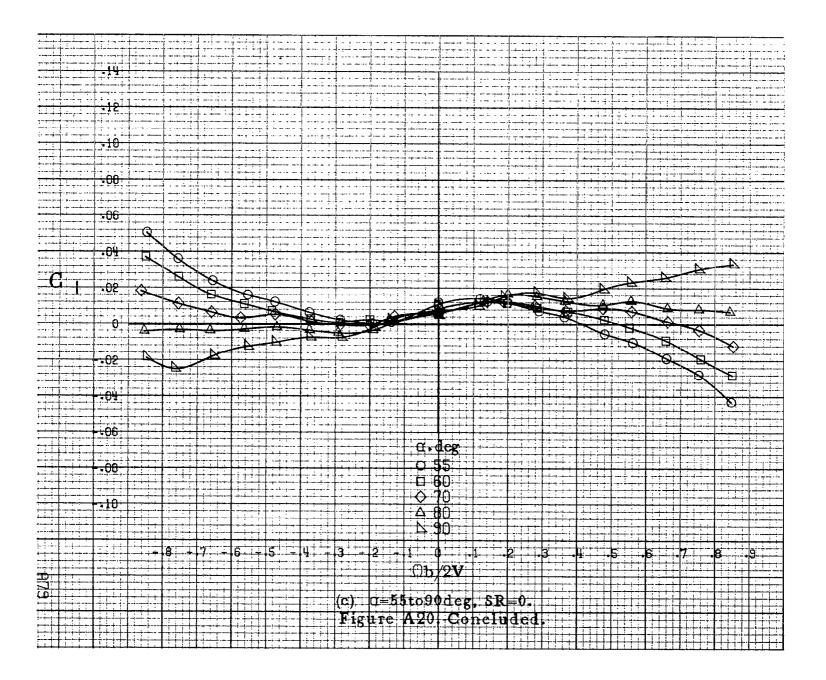


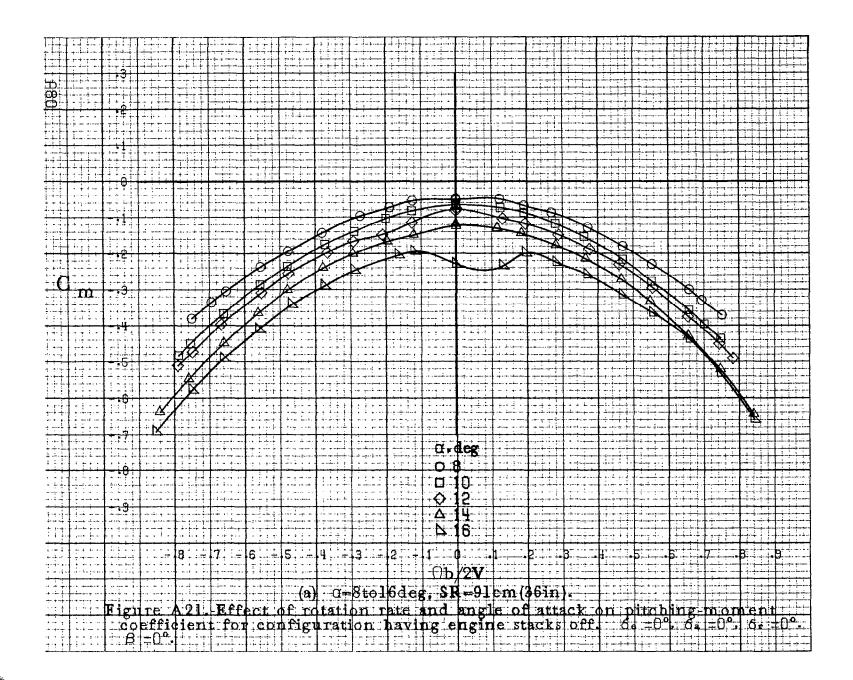


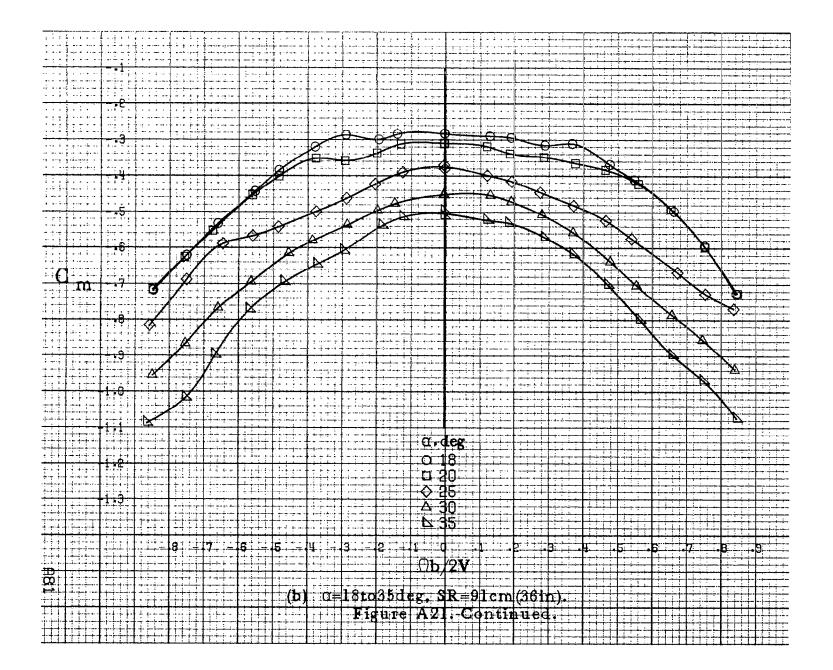


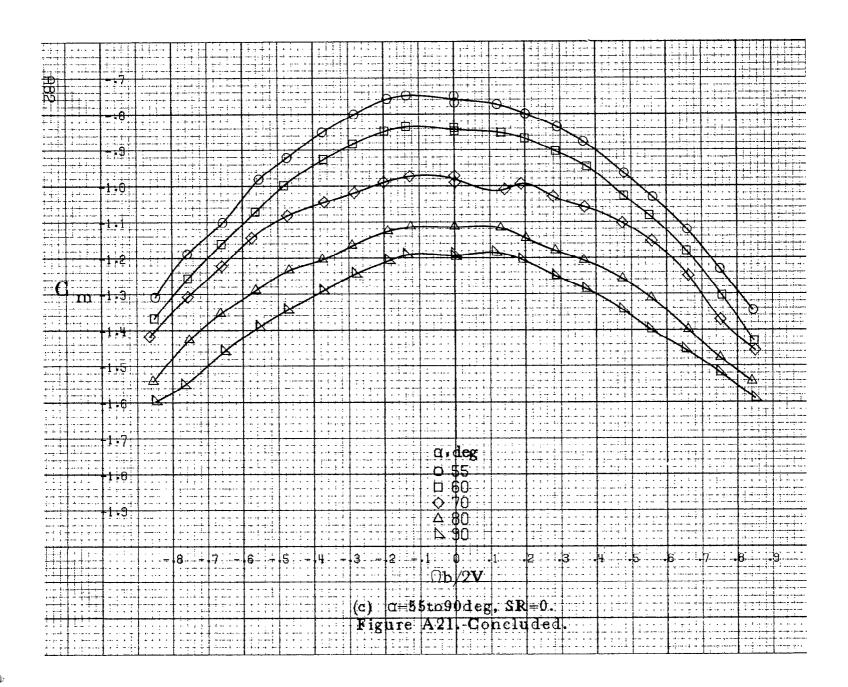




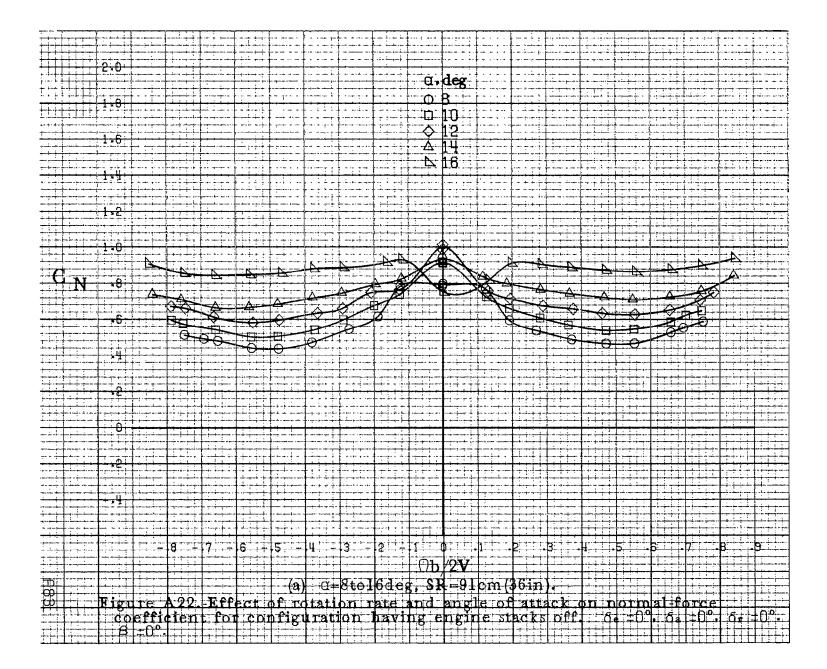


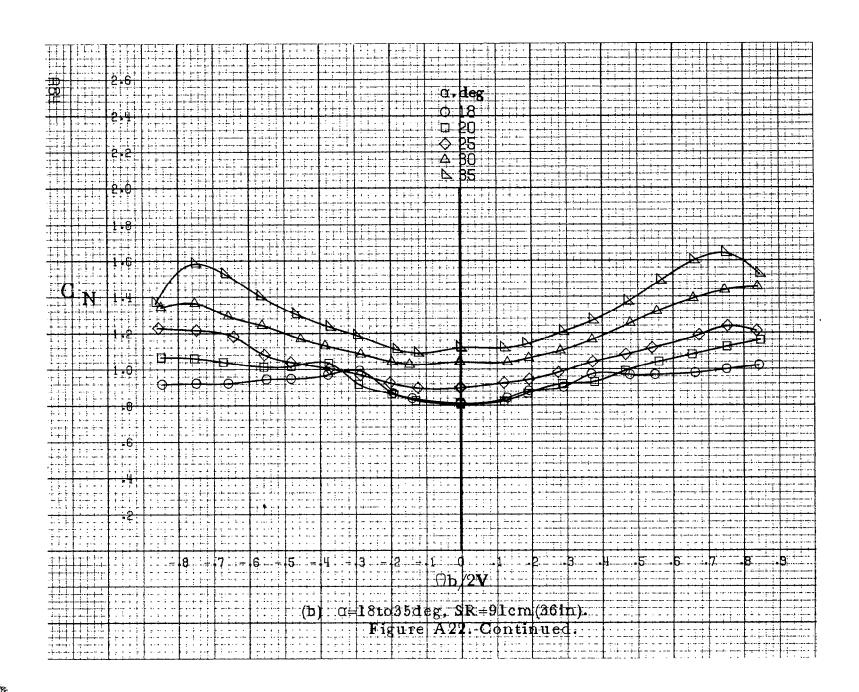


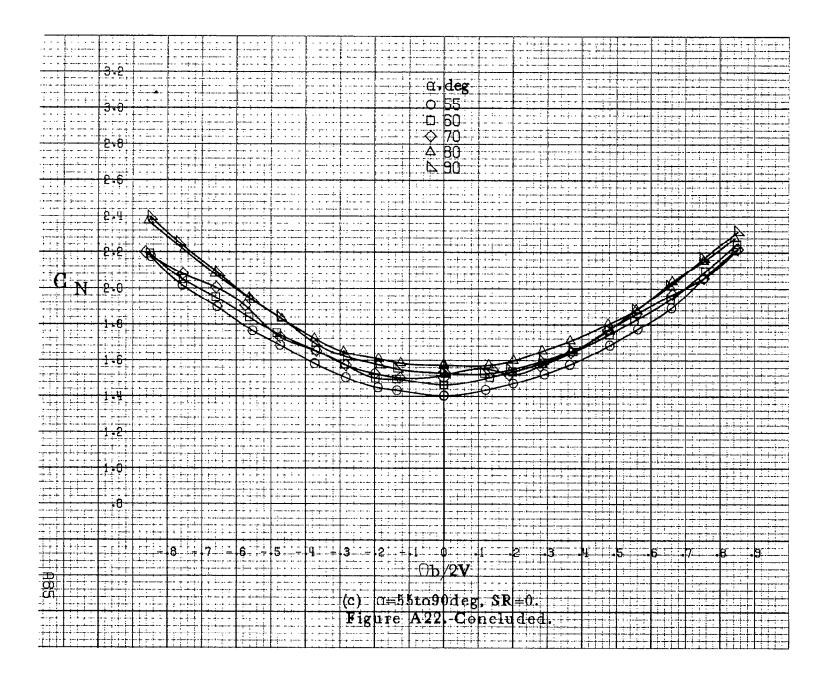


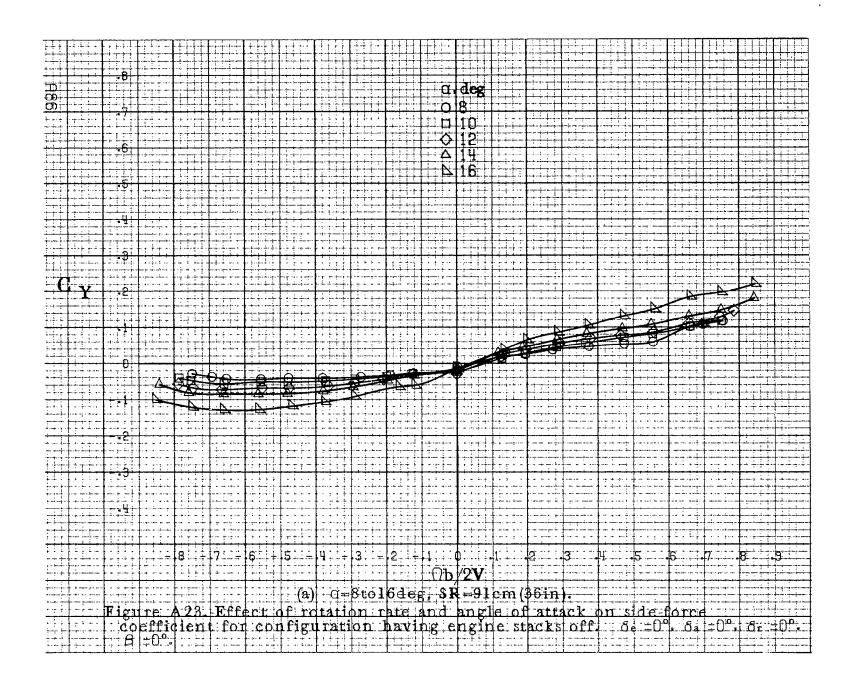


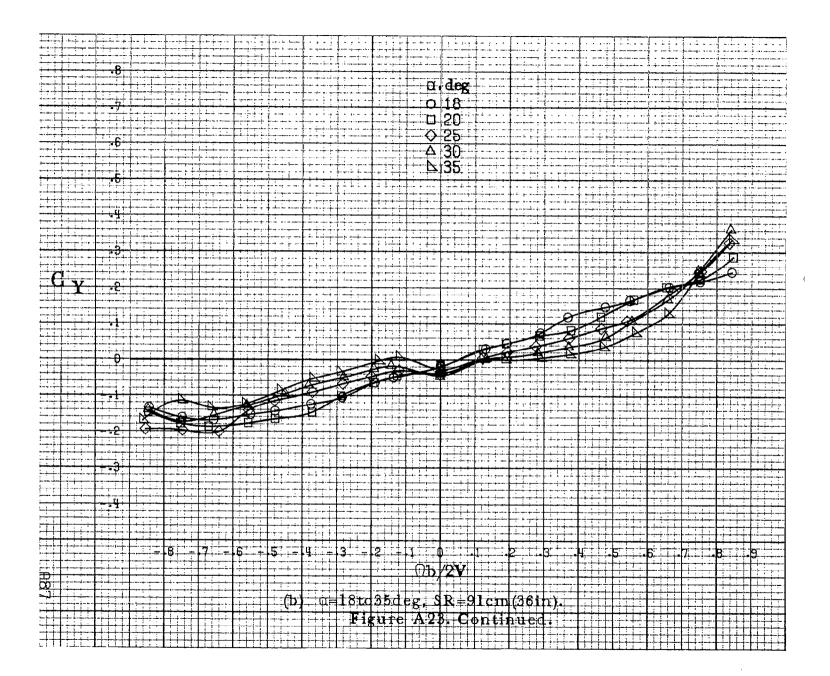


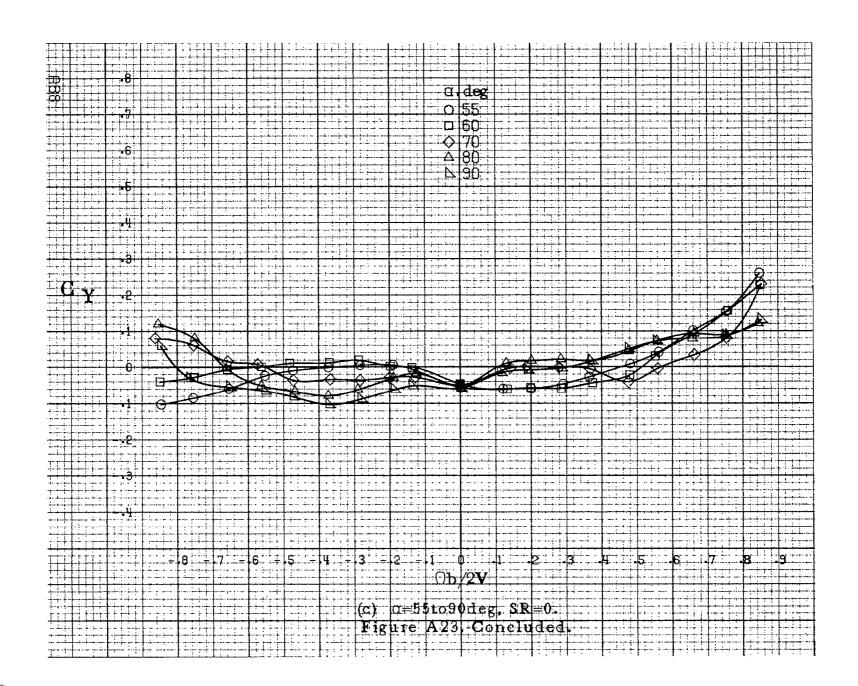


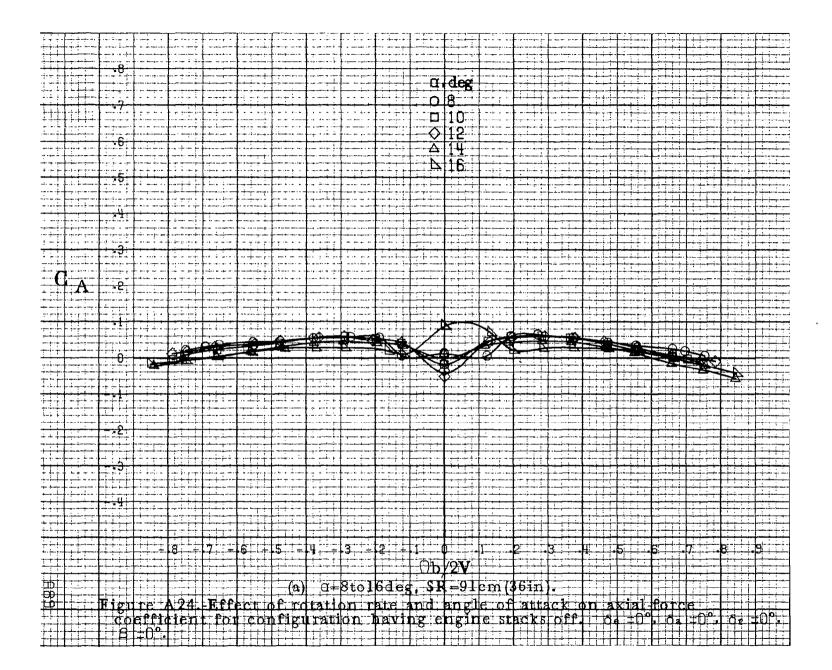




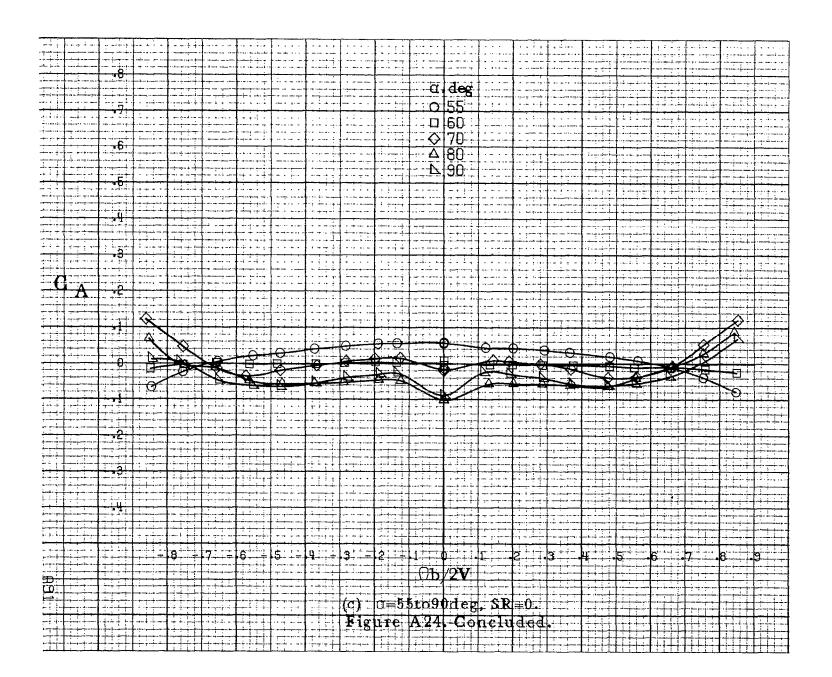


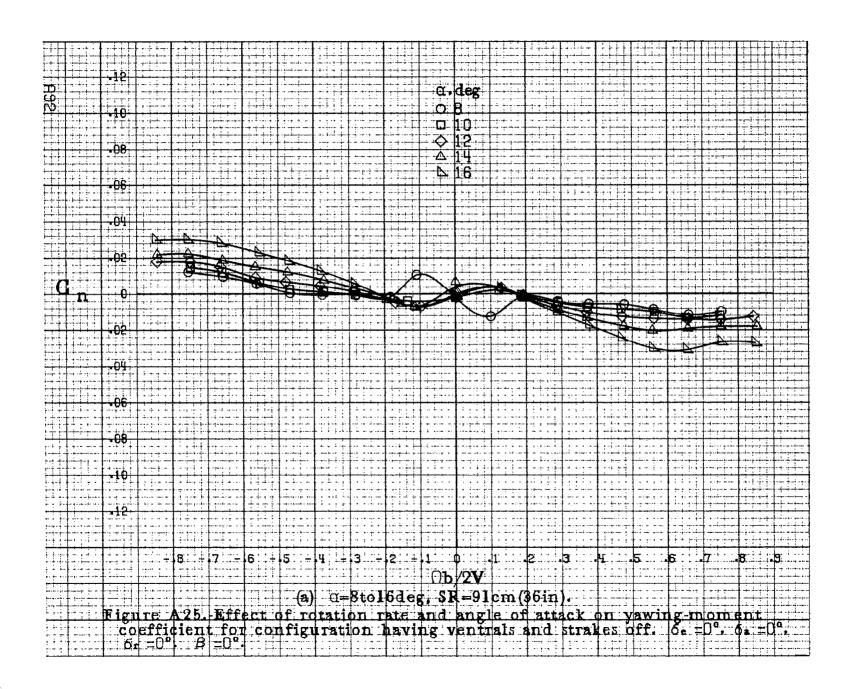


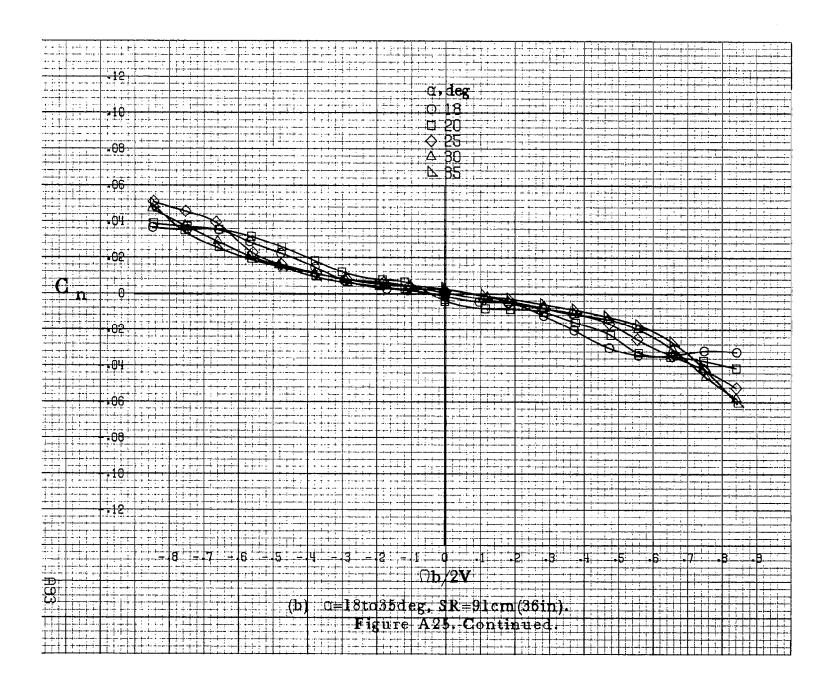




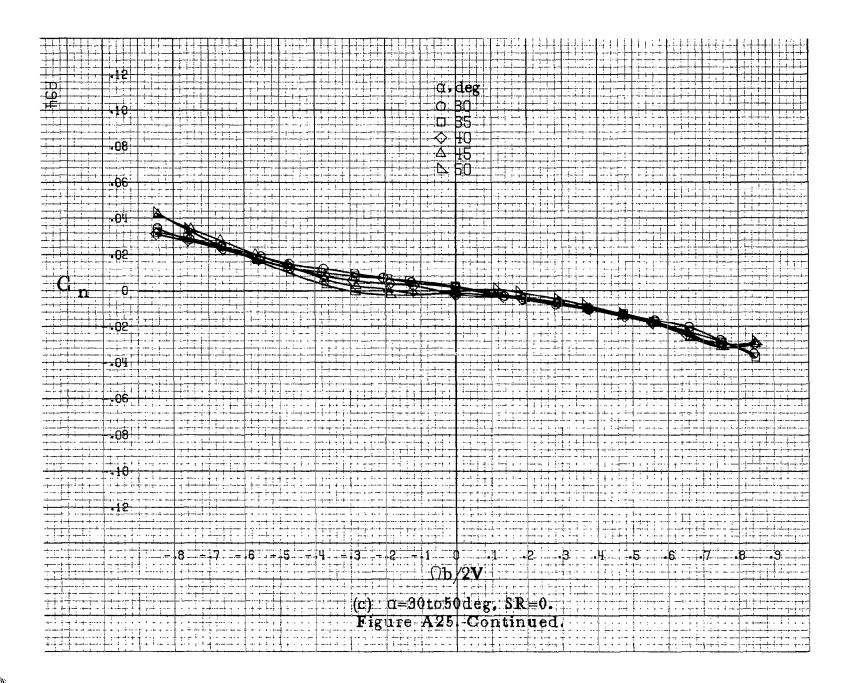
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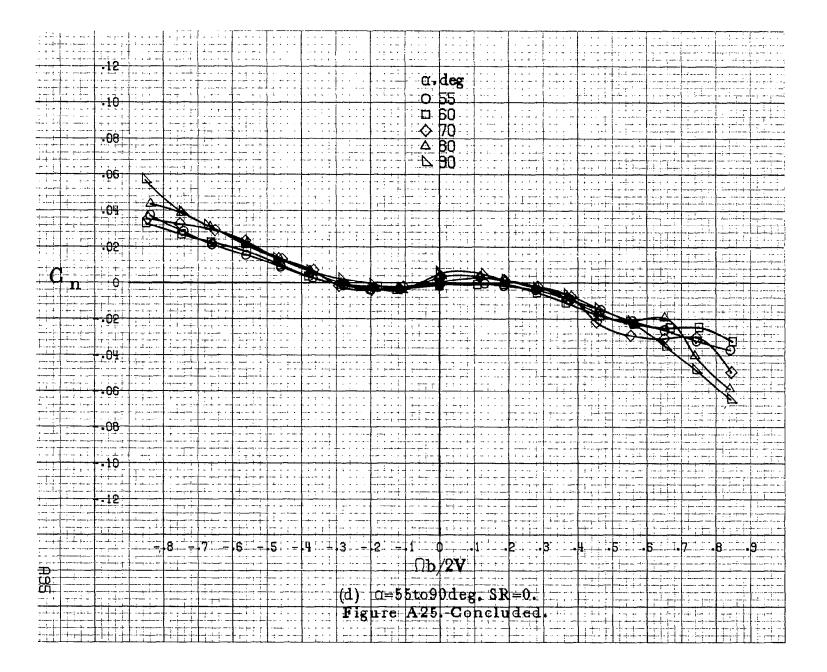


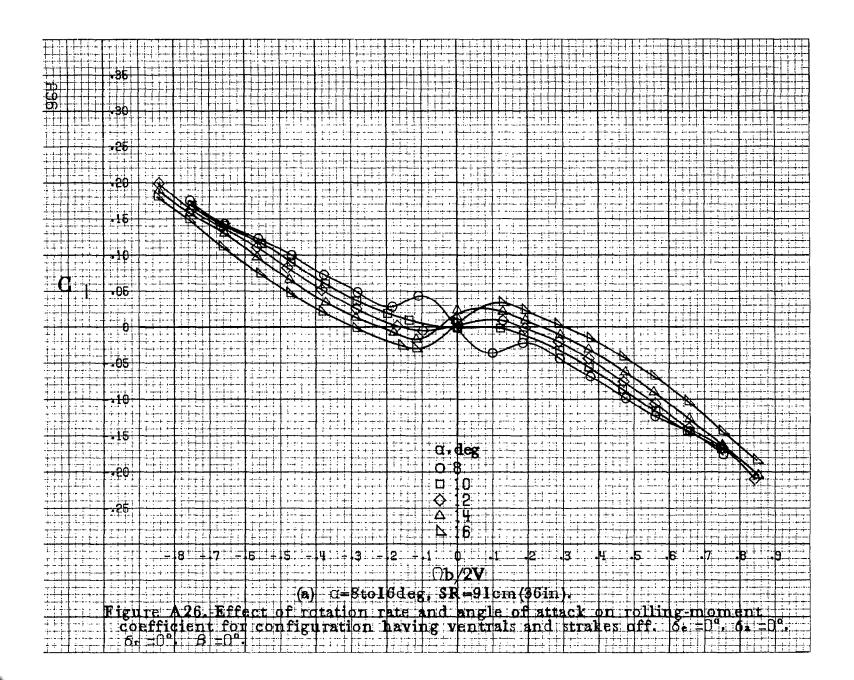


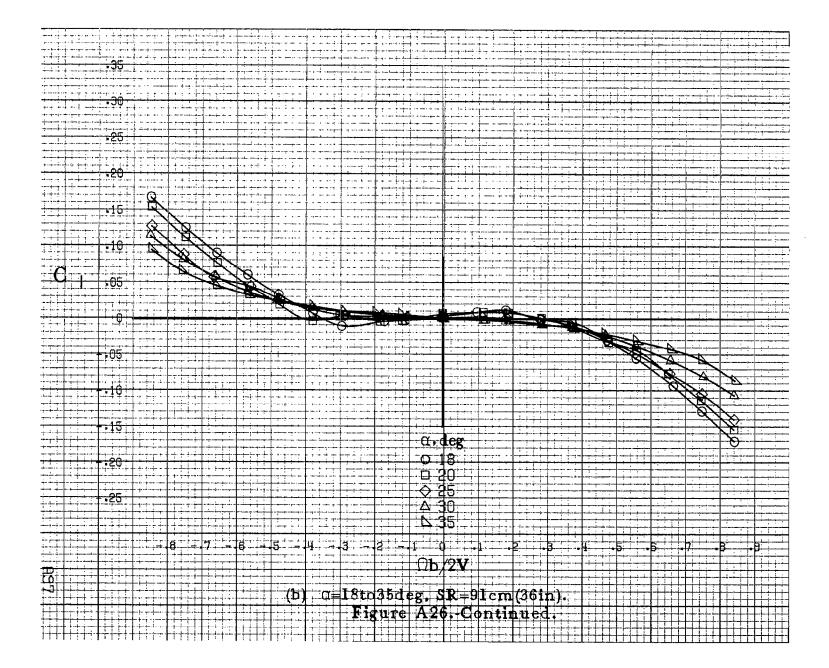


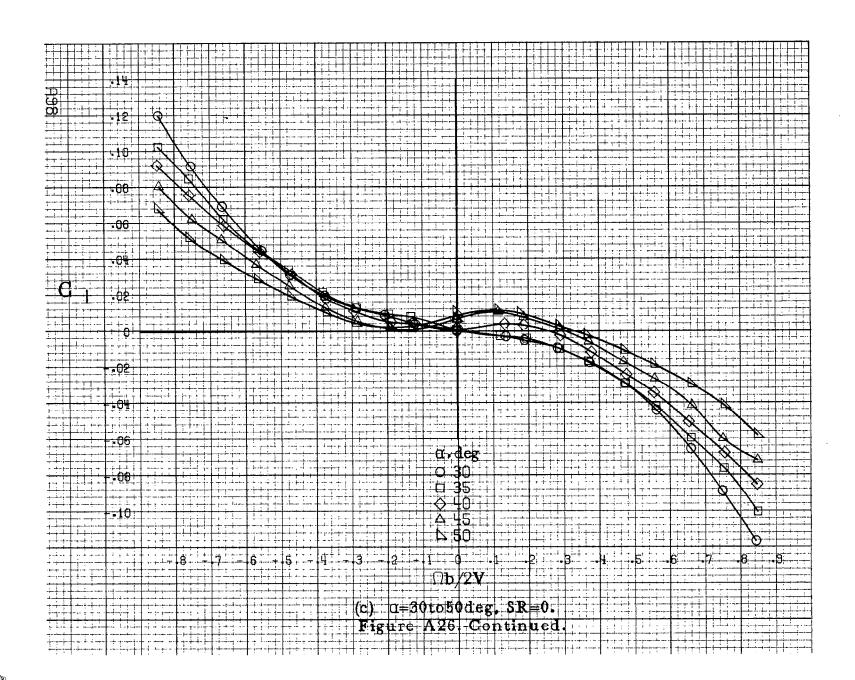
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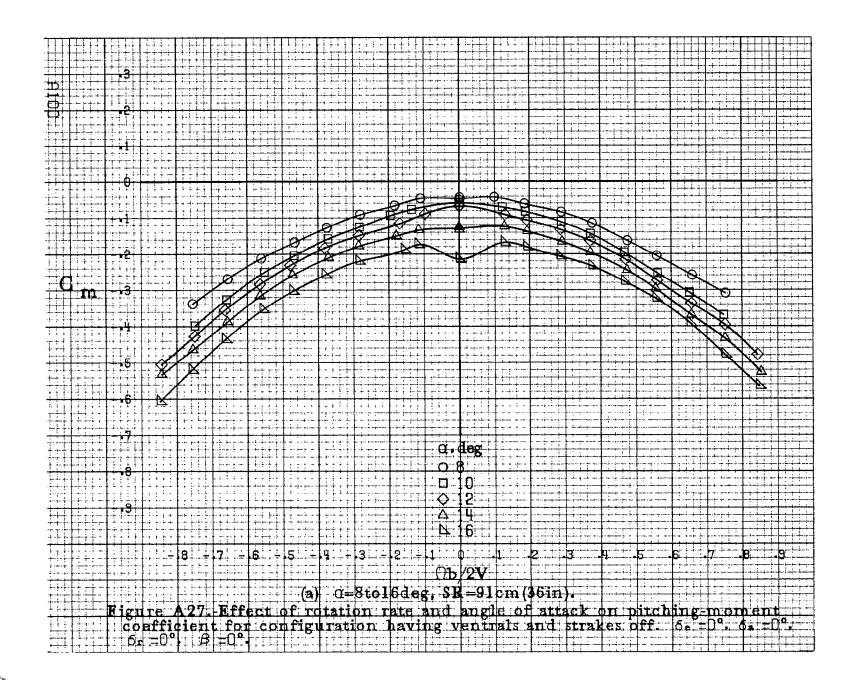


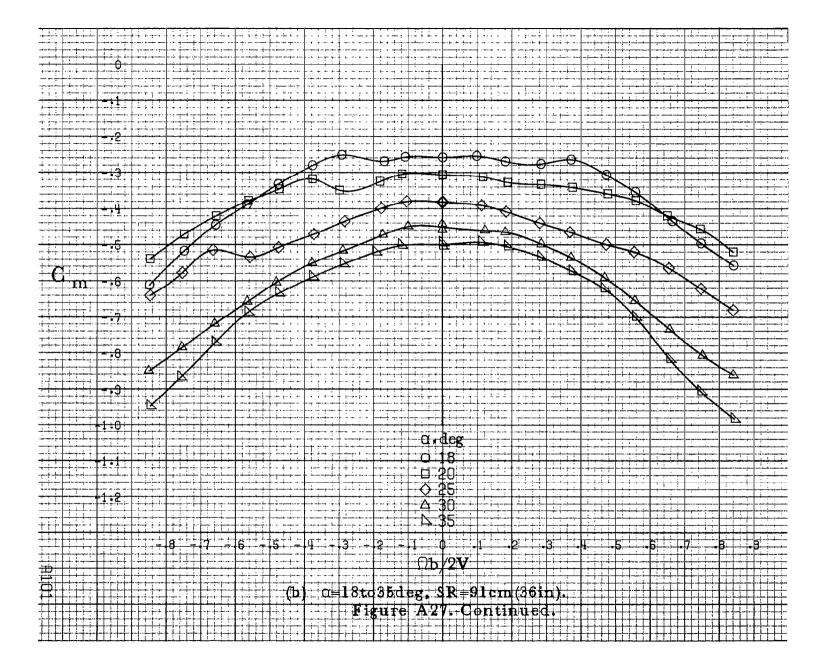


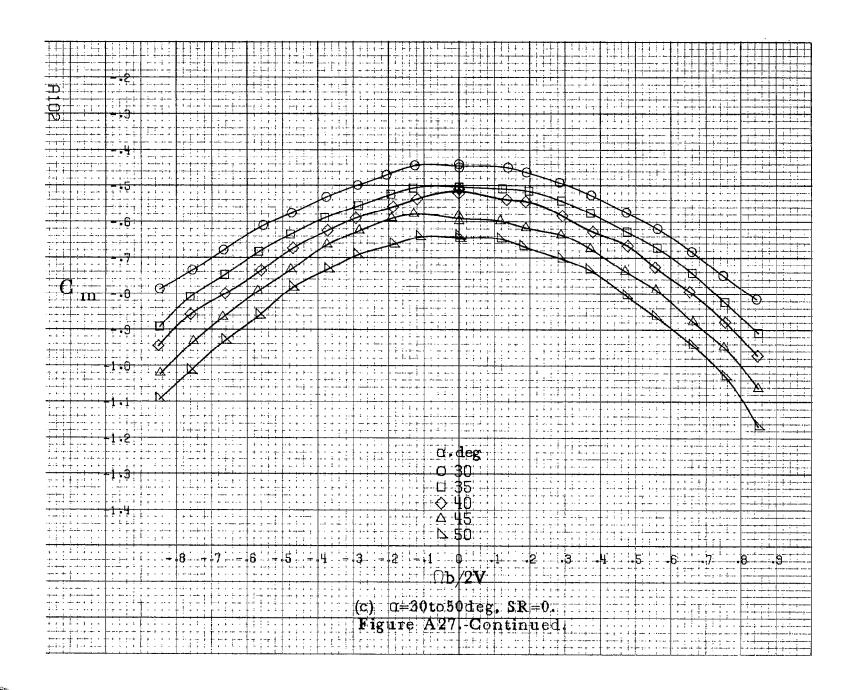


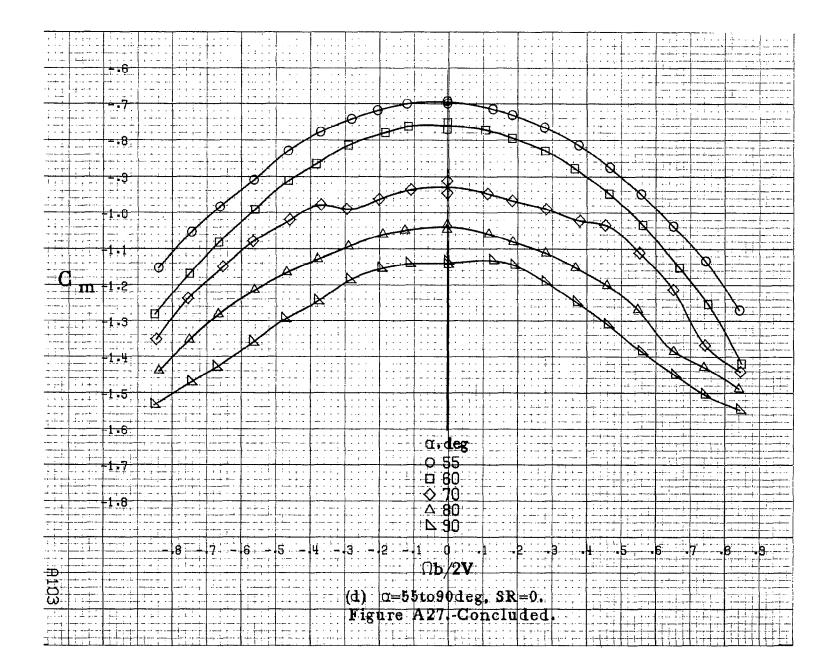


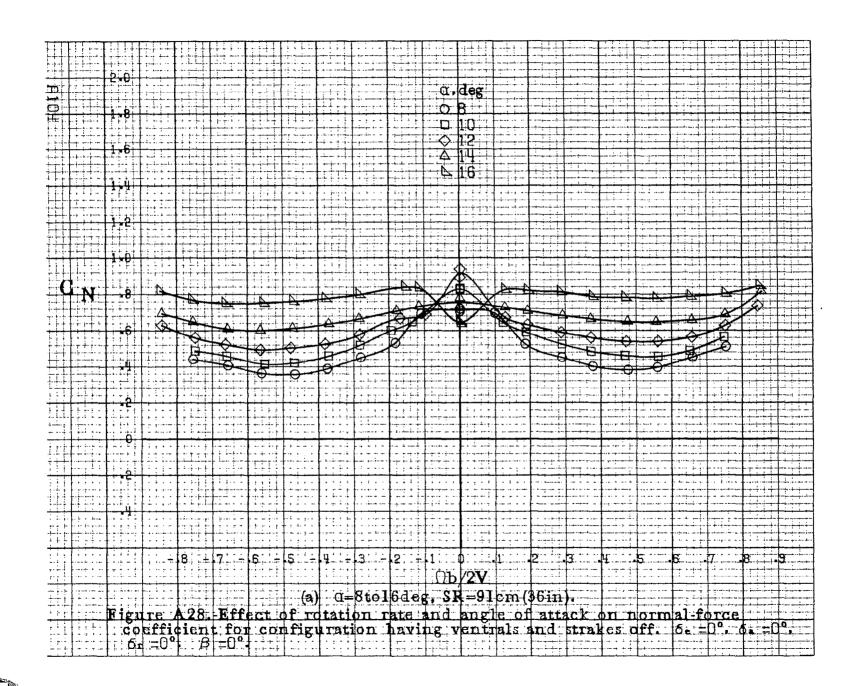
□ 60 ◆ 70 (d) a=55to90deg, SR=0. Figure A26.-Concluded.

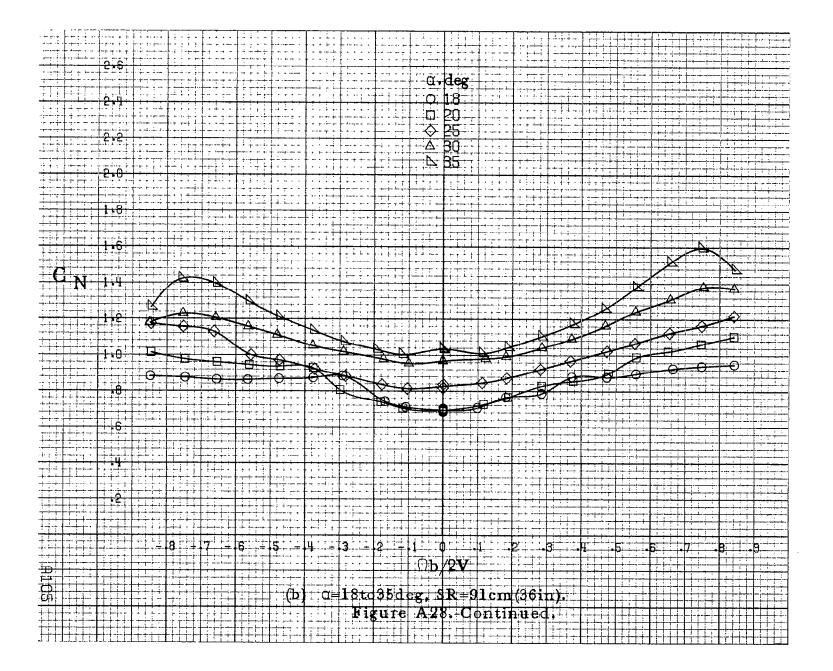


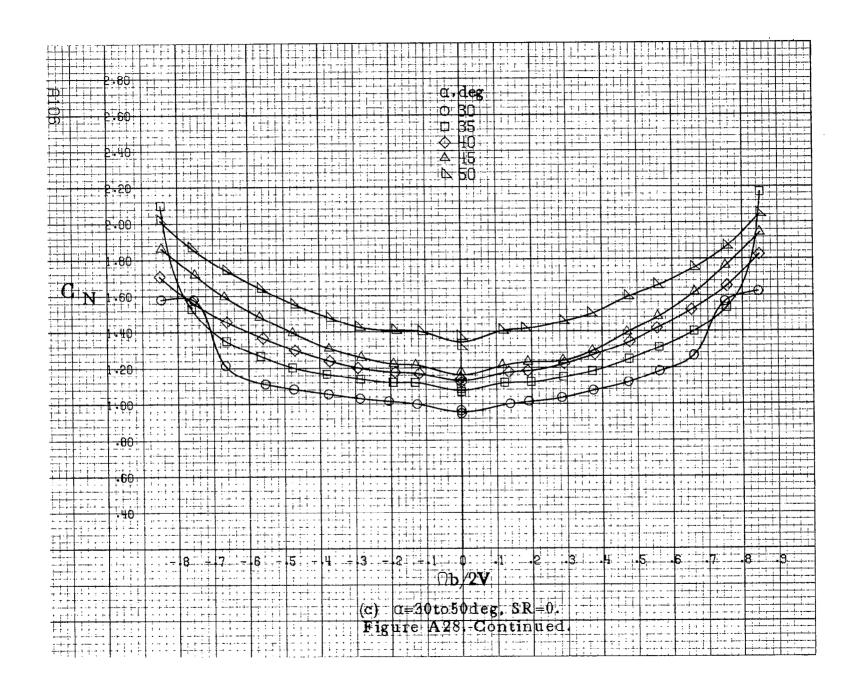


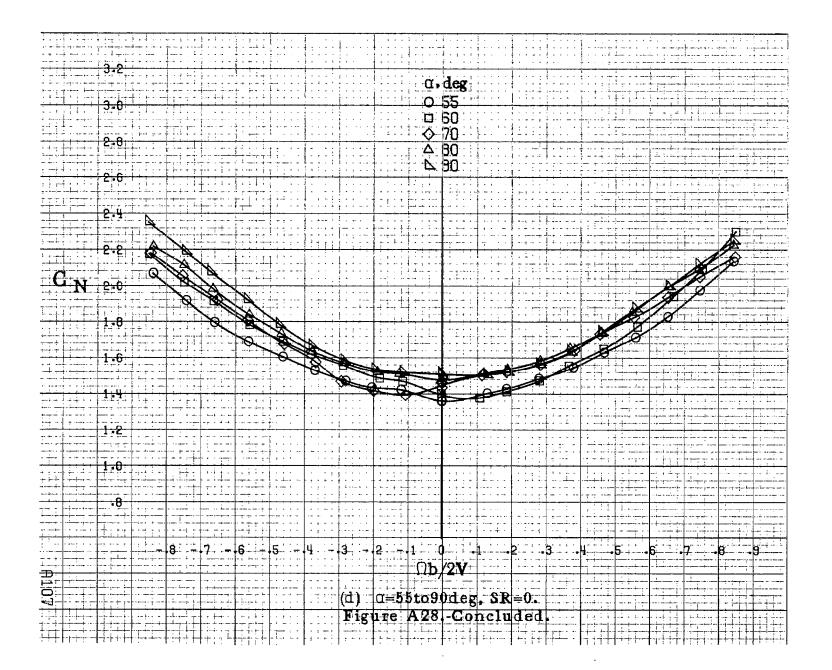


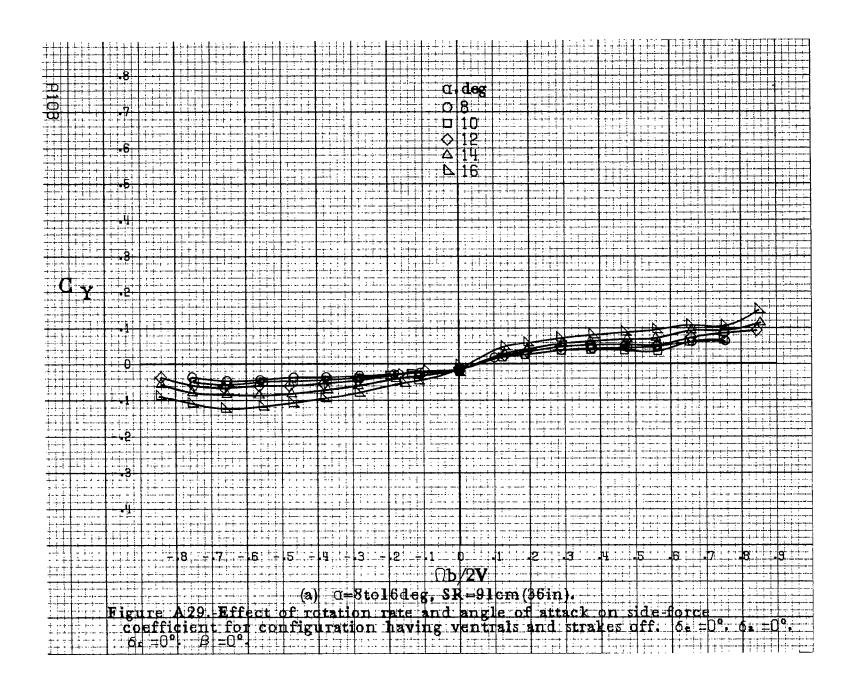


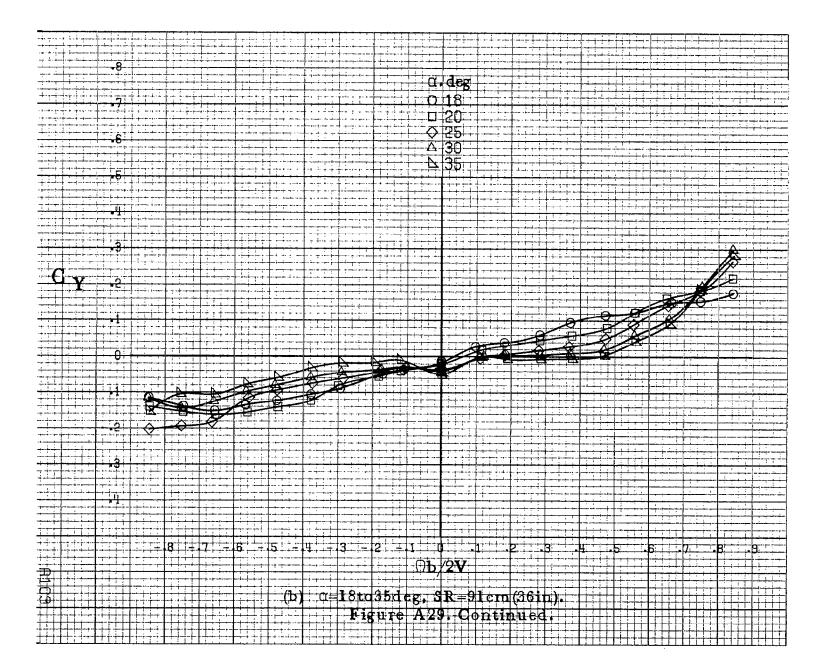


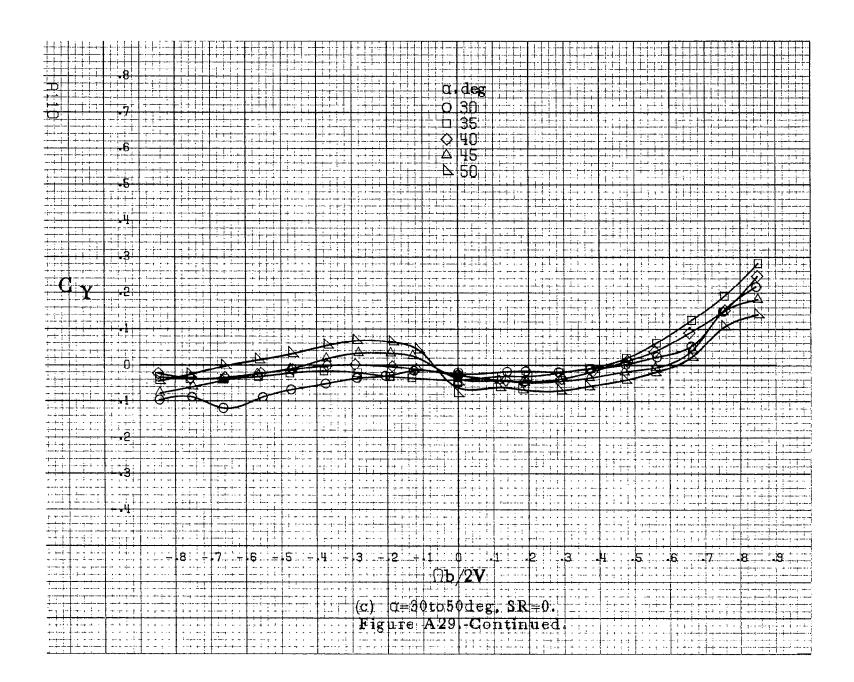




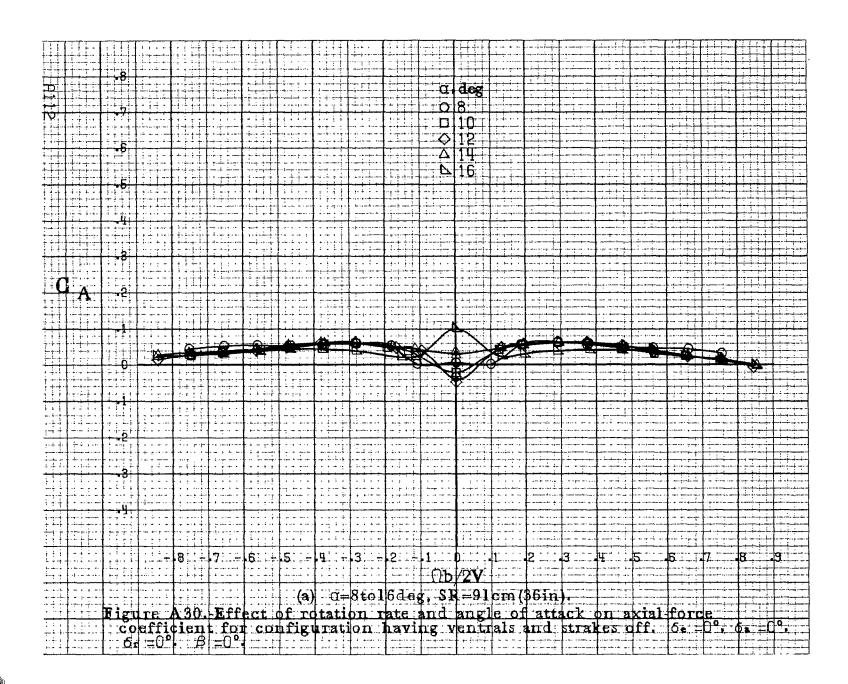


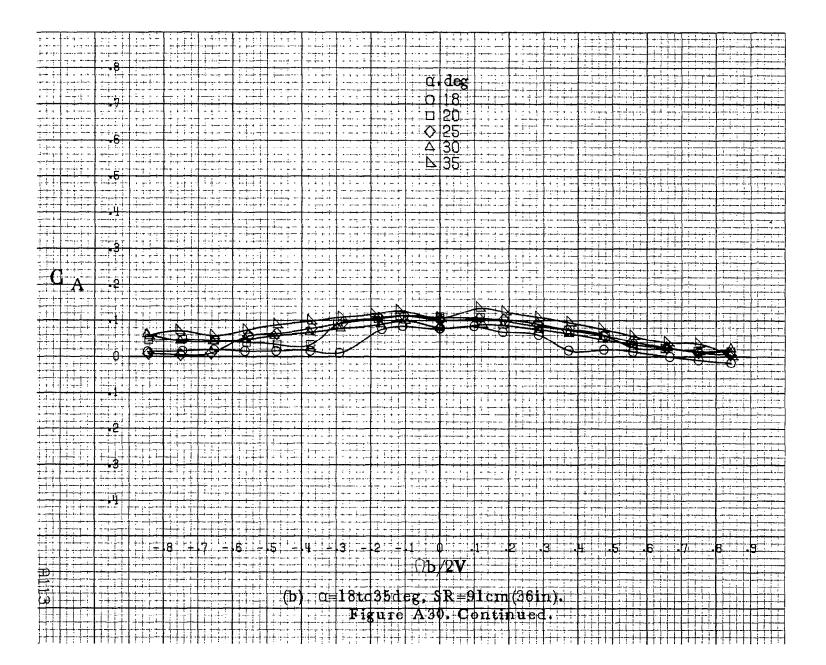


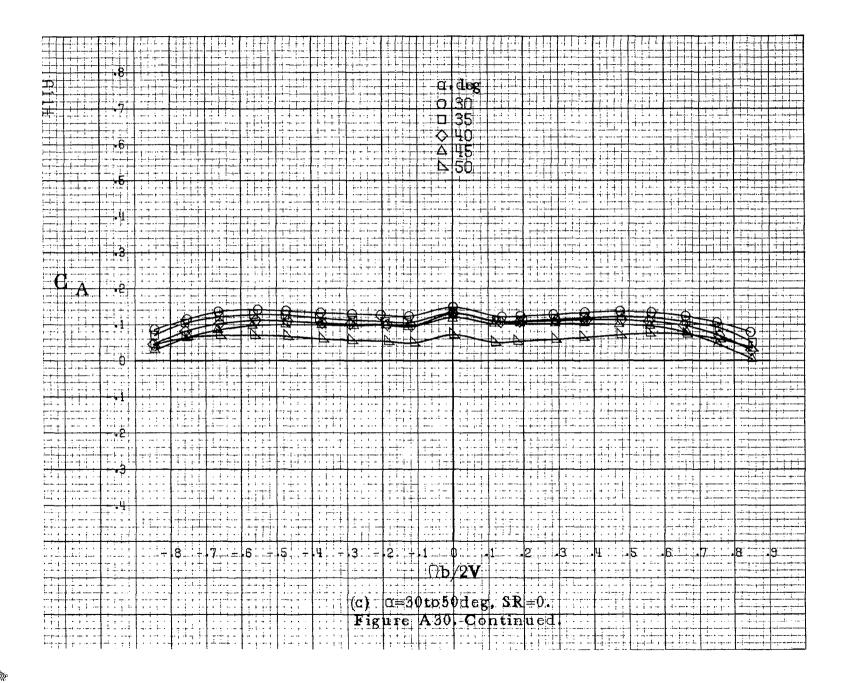




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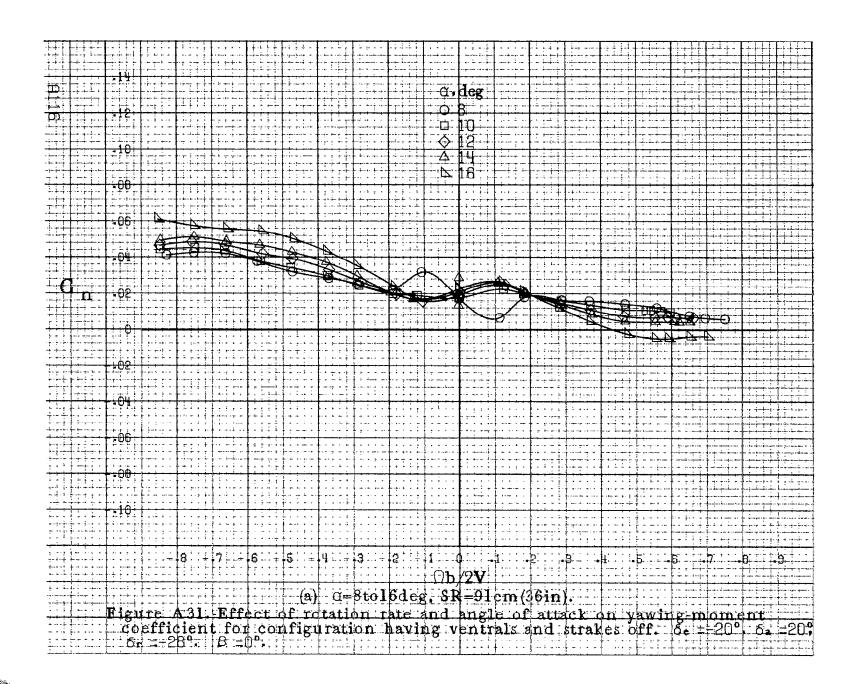


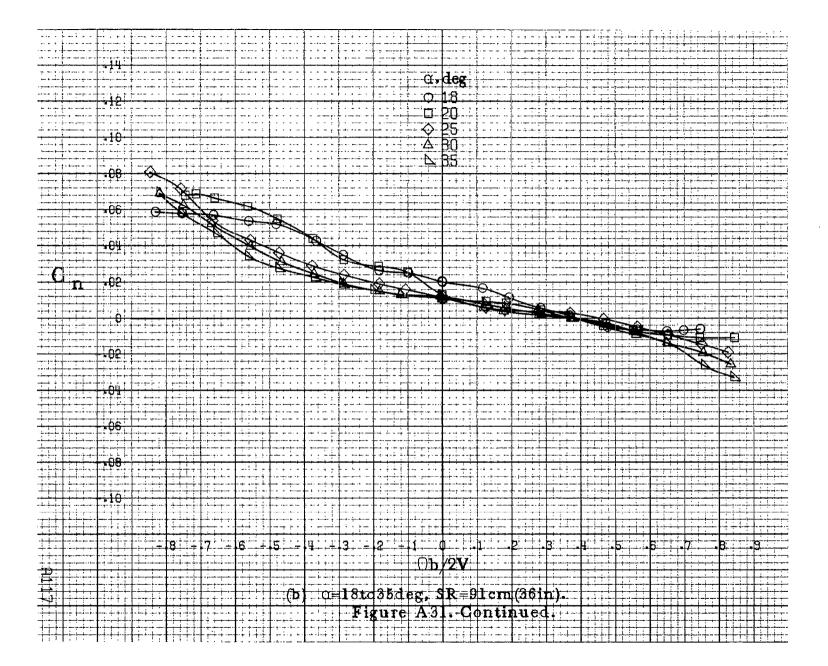


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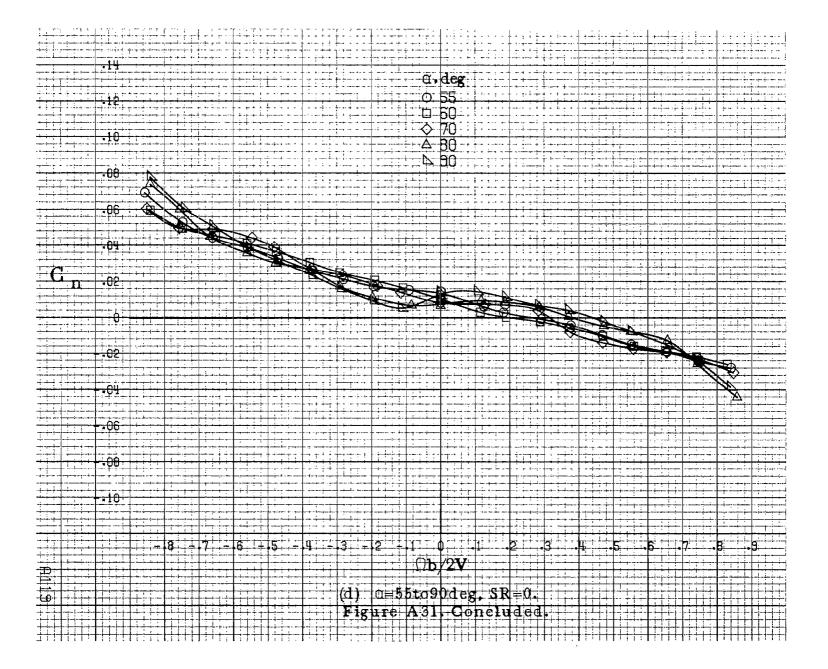
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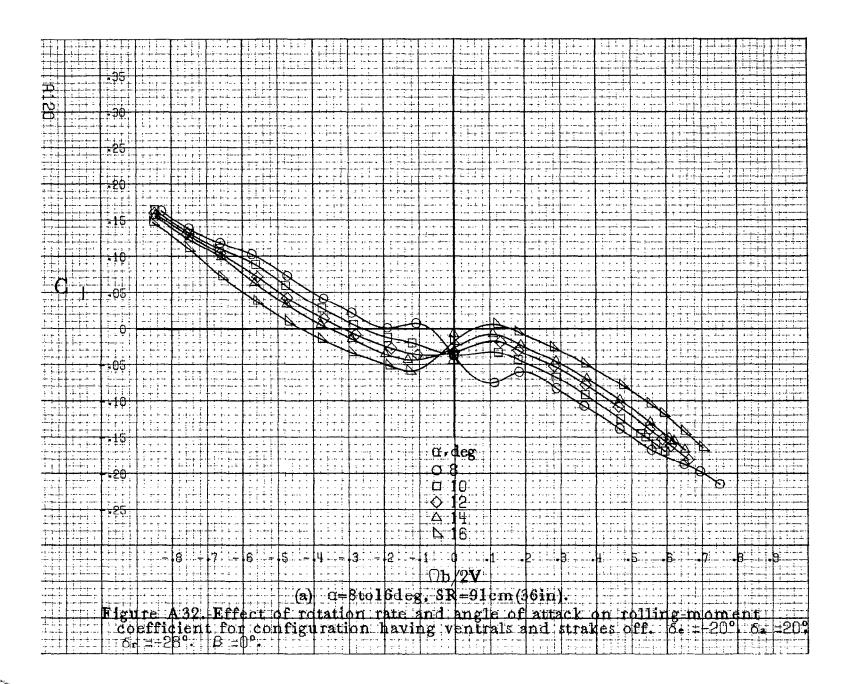
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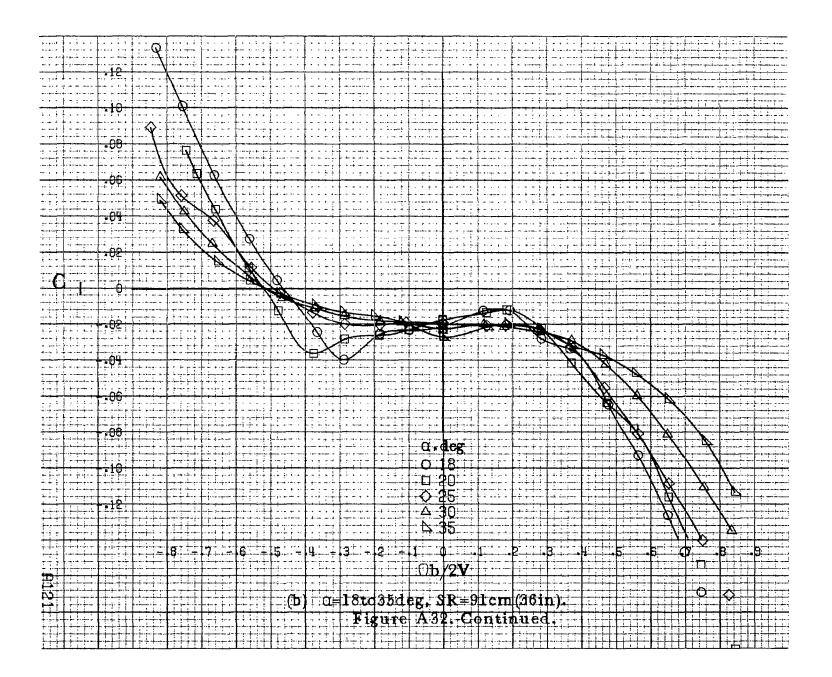


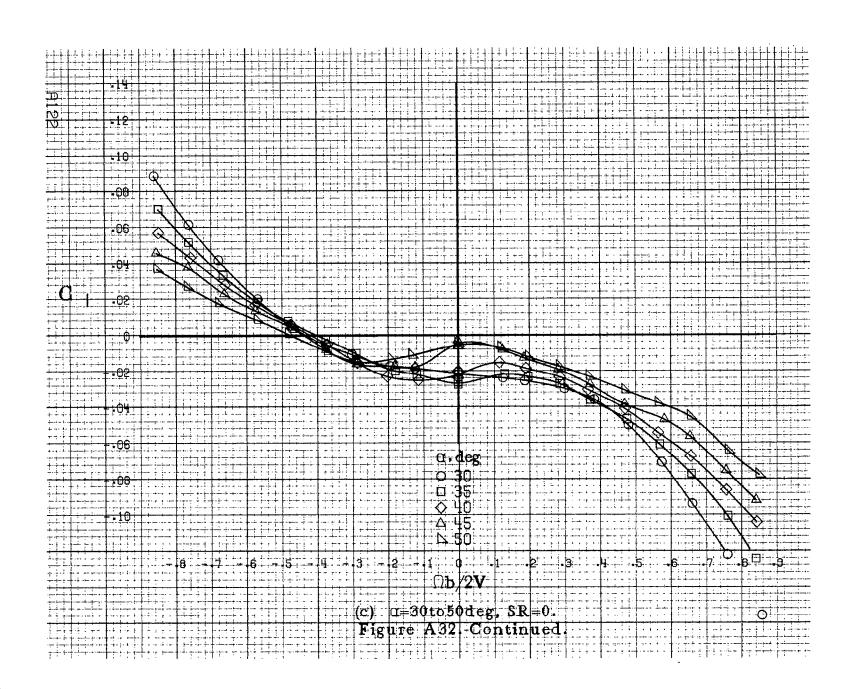


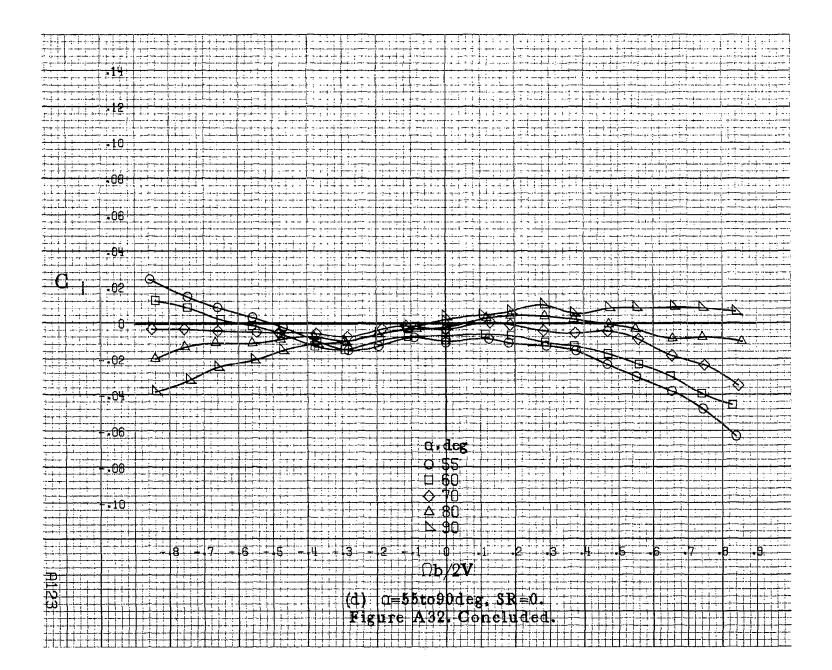
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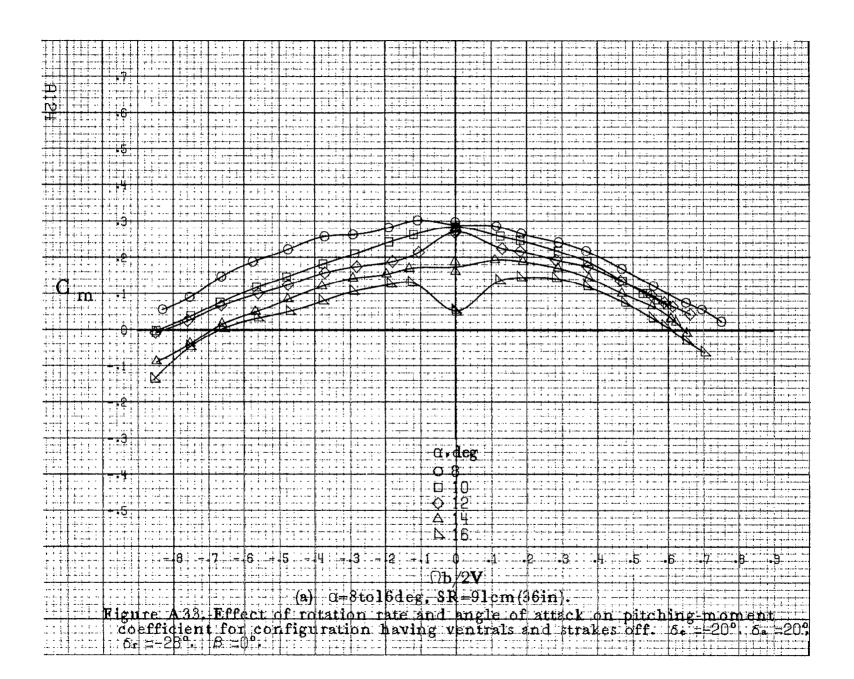


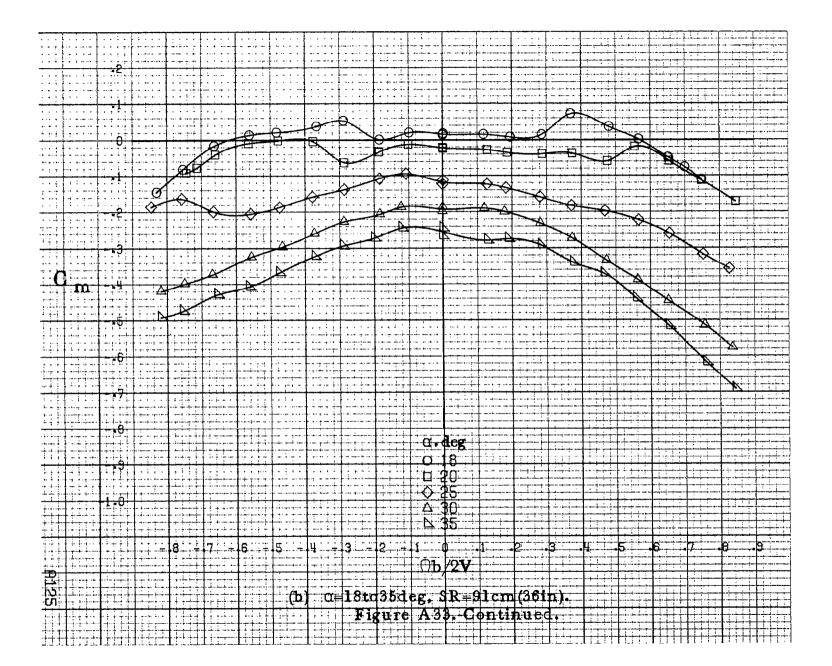








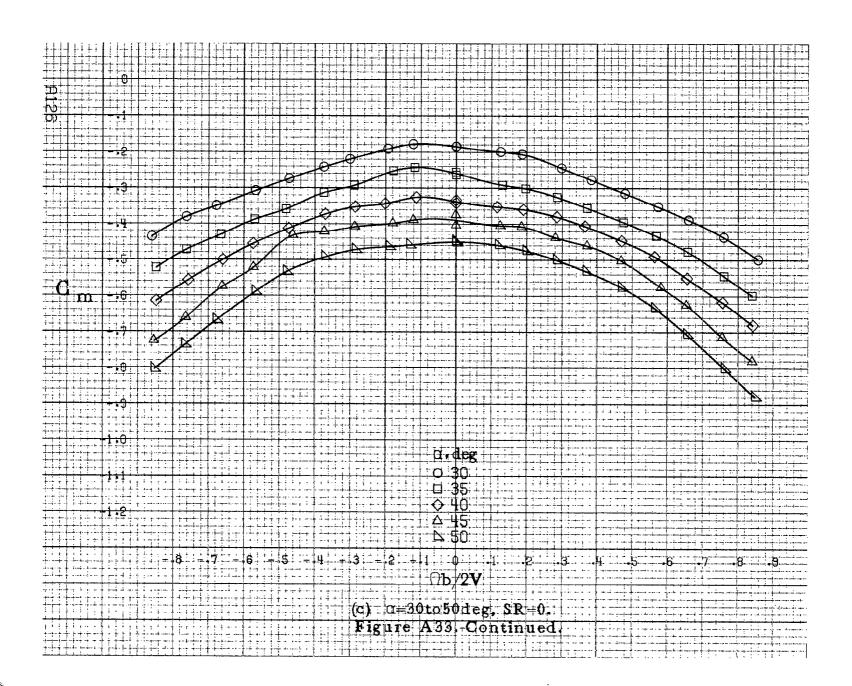


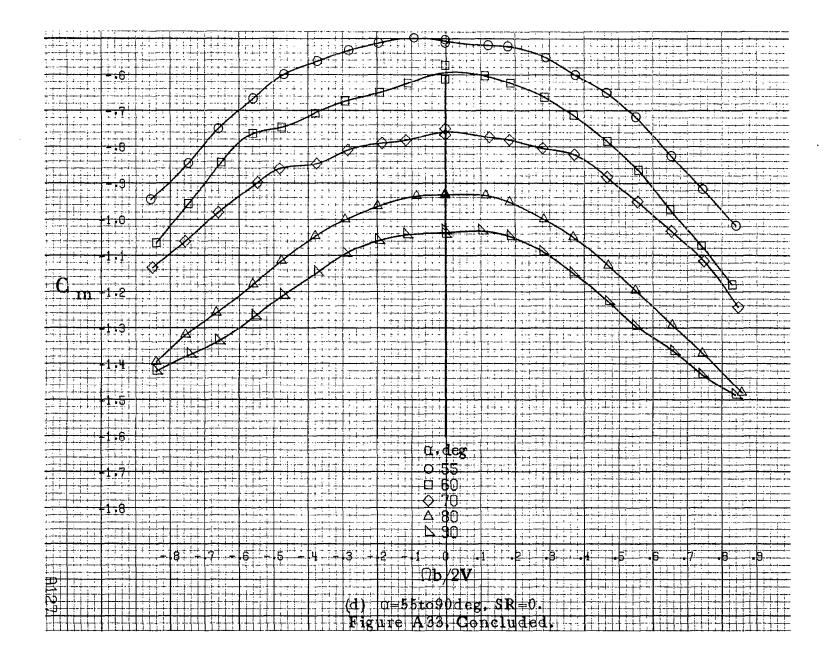


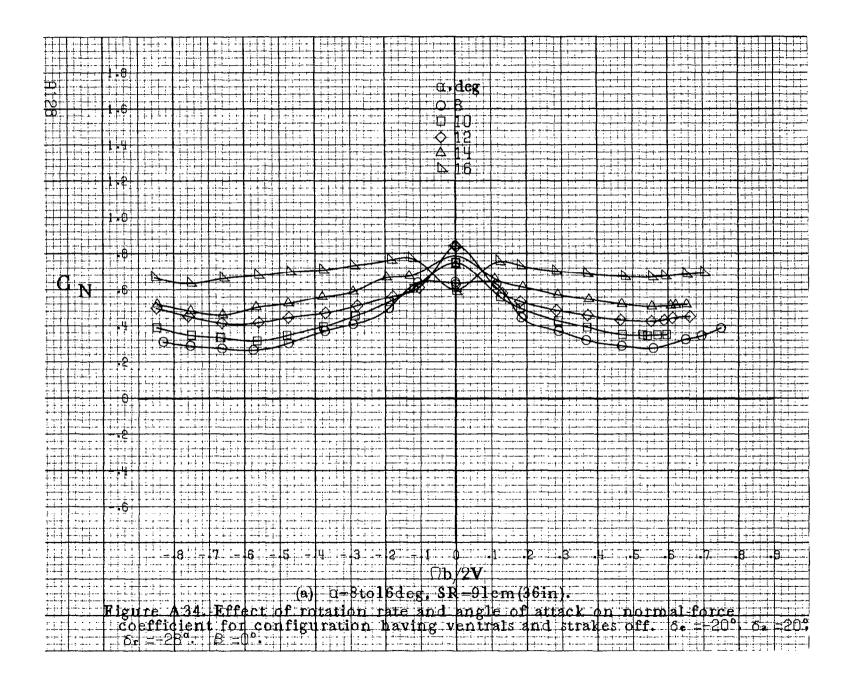
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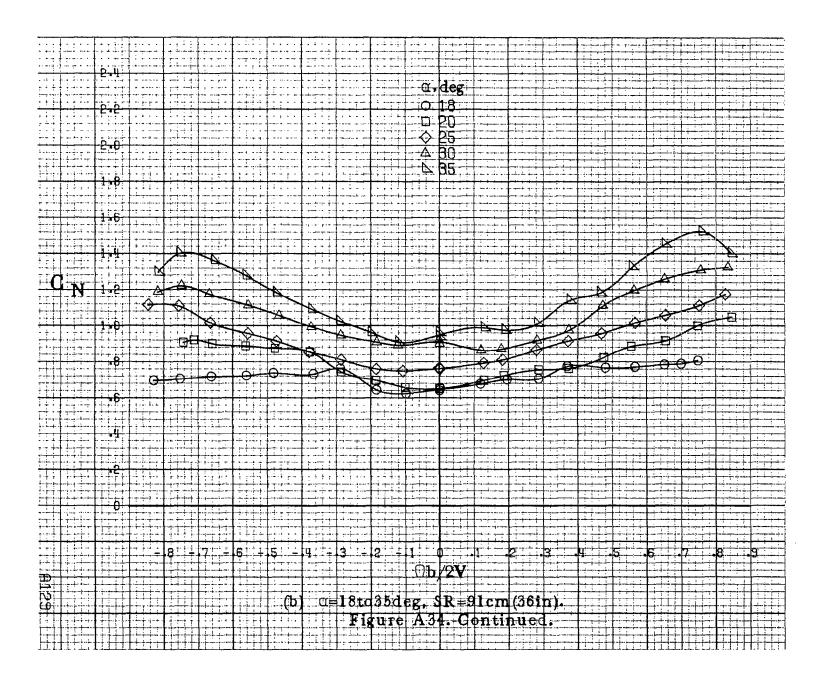
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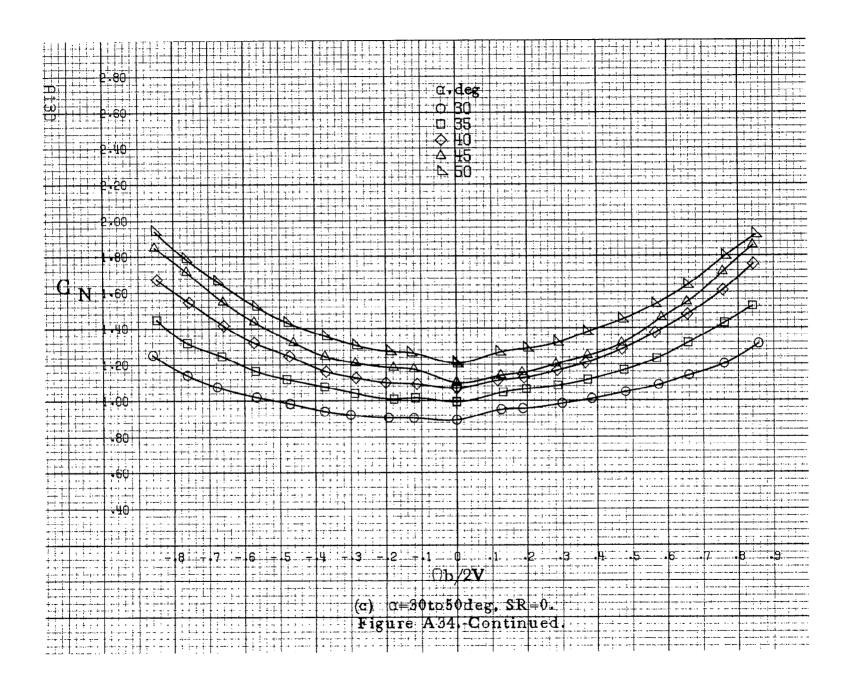
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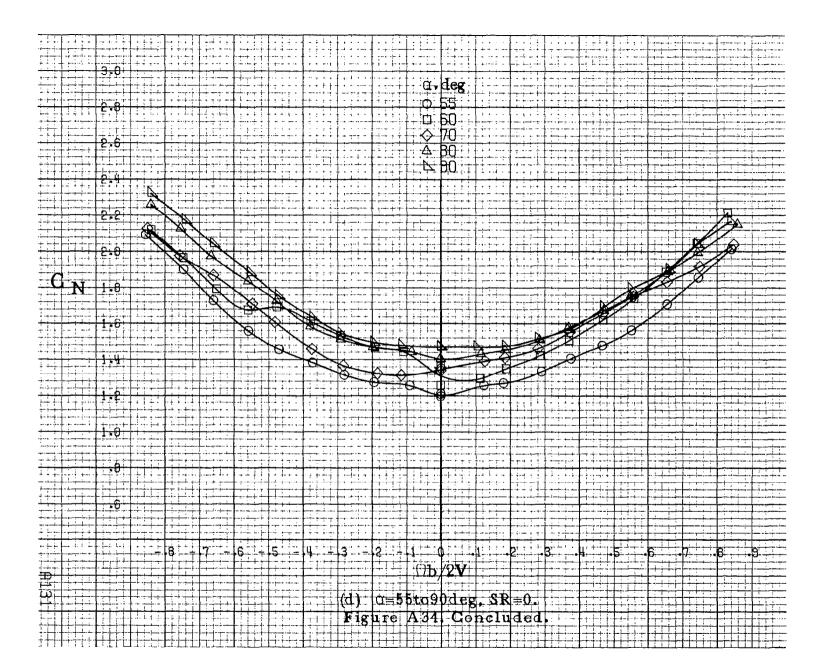


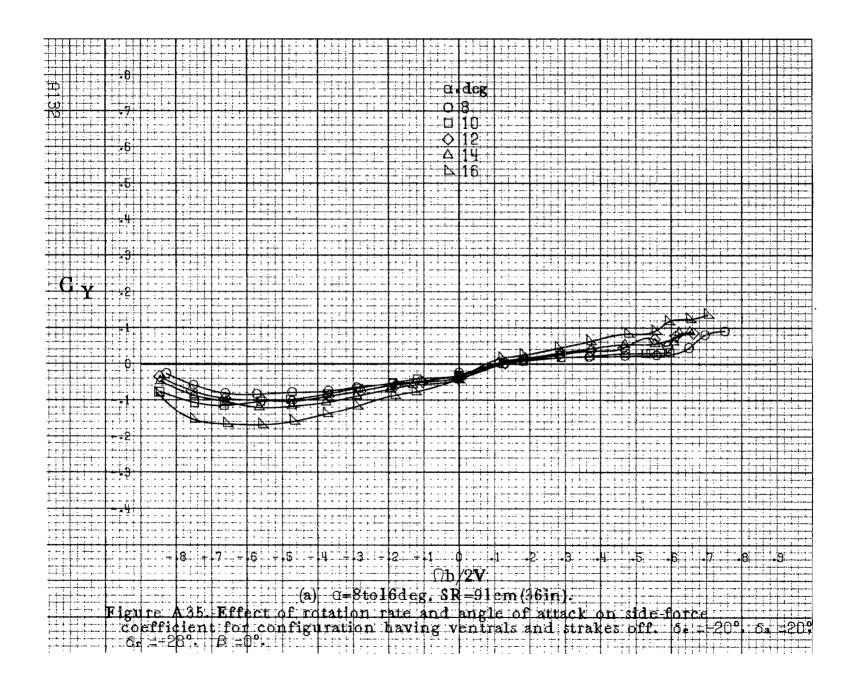


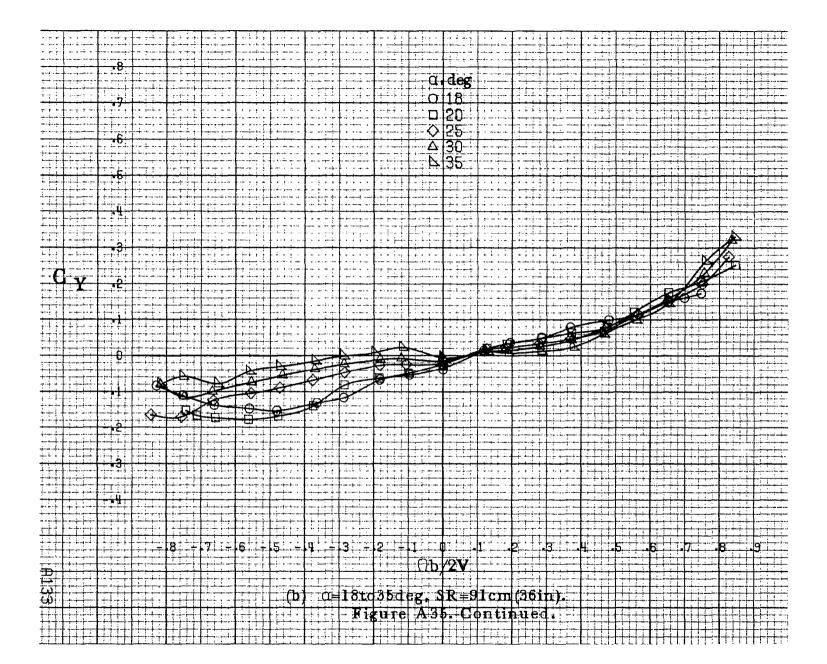


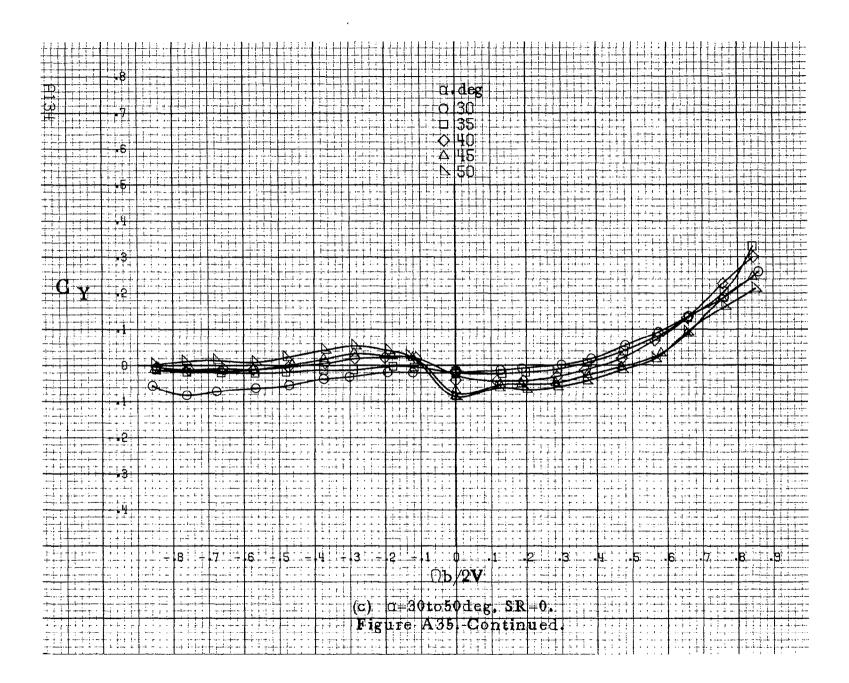




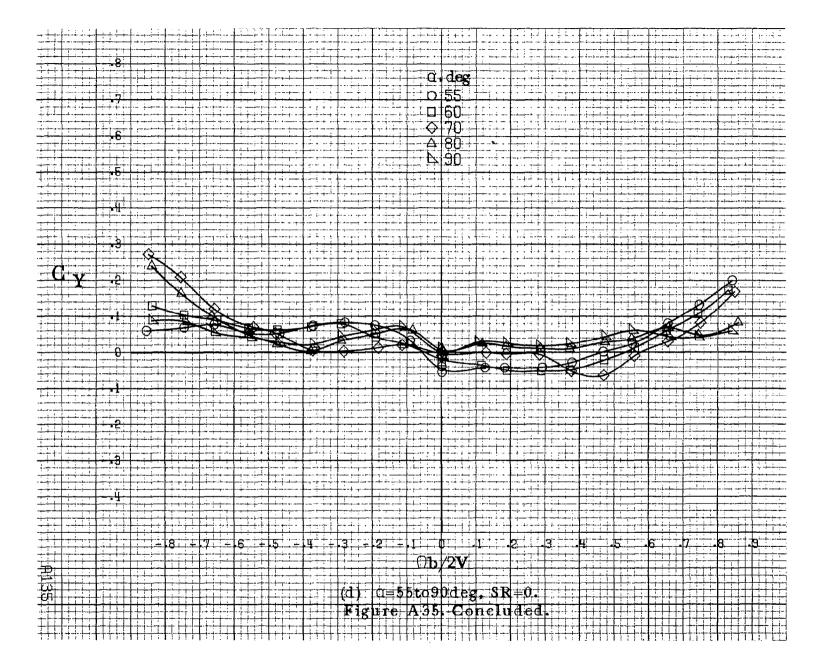


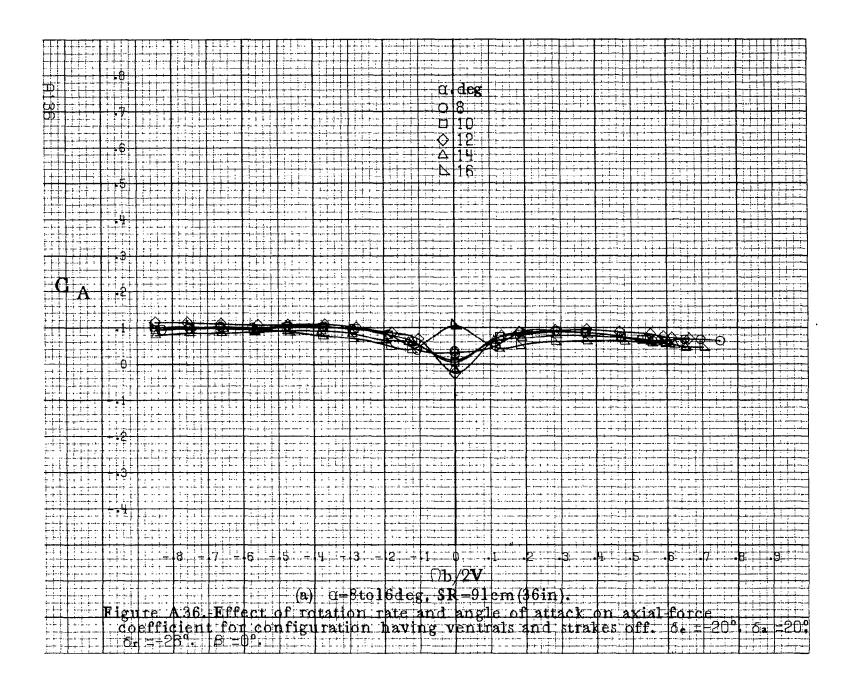


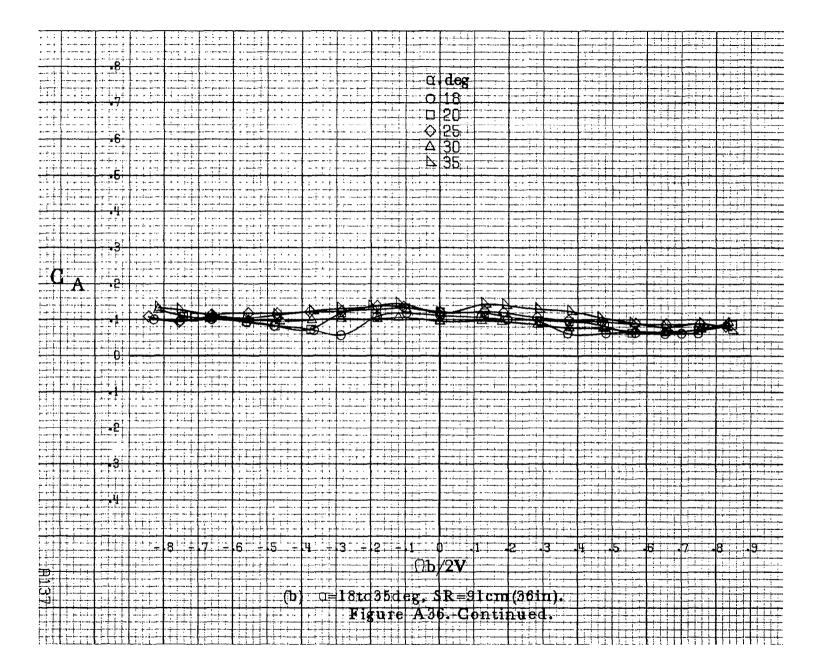


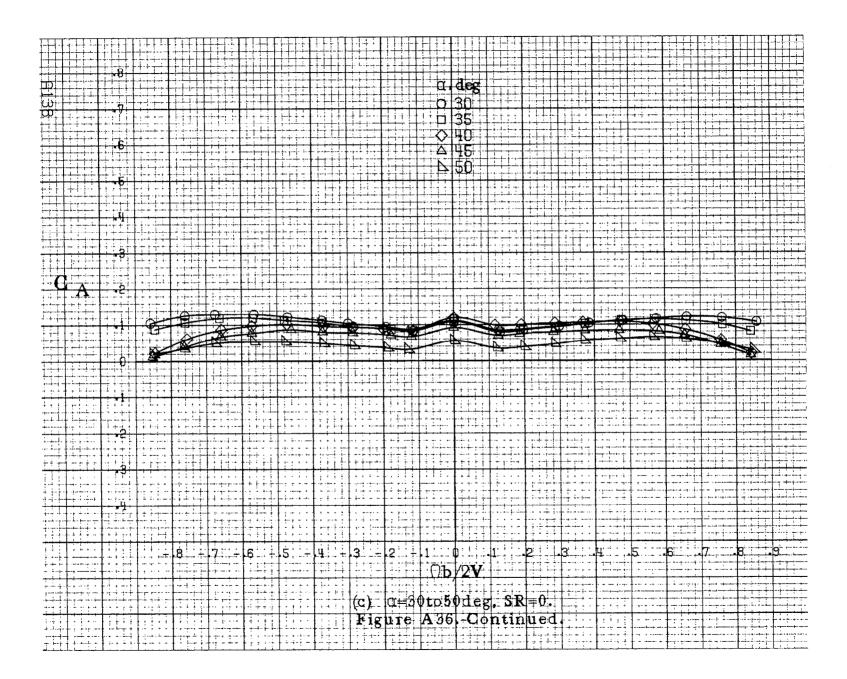


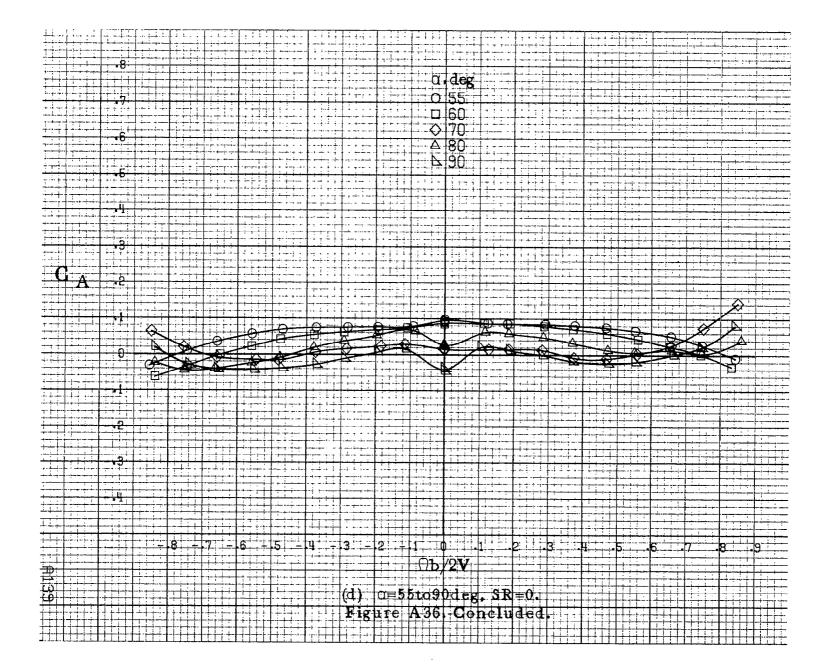


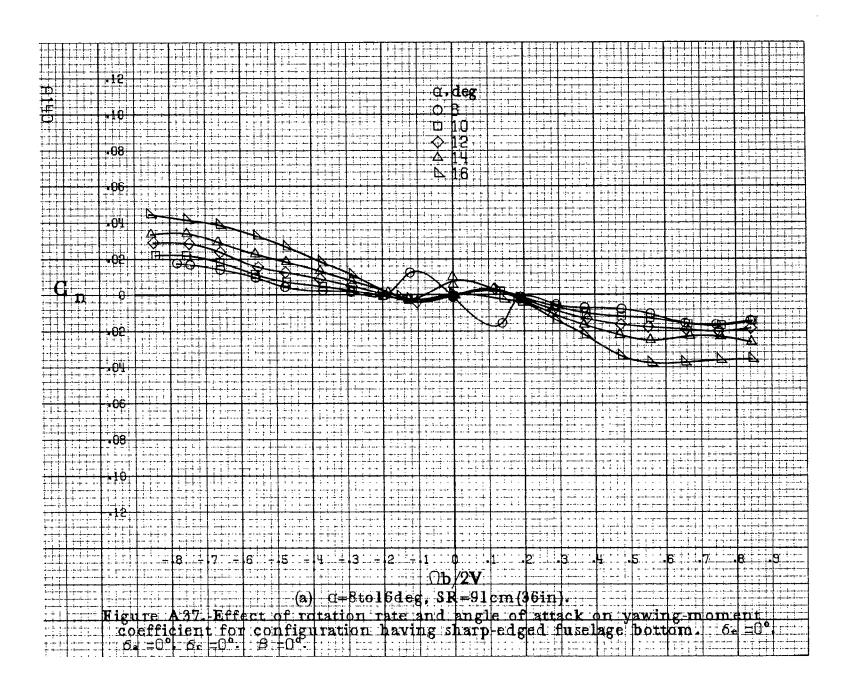


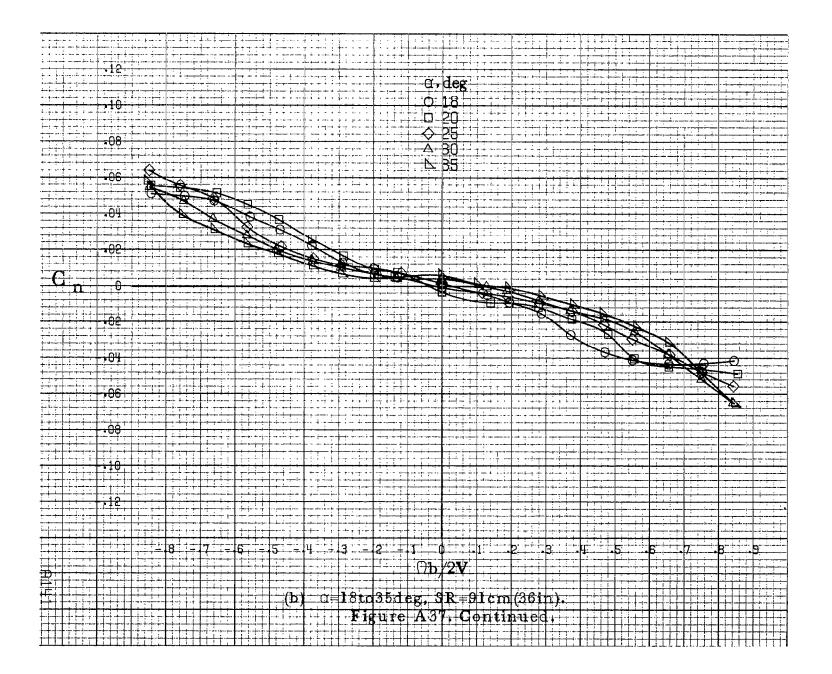


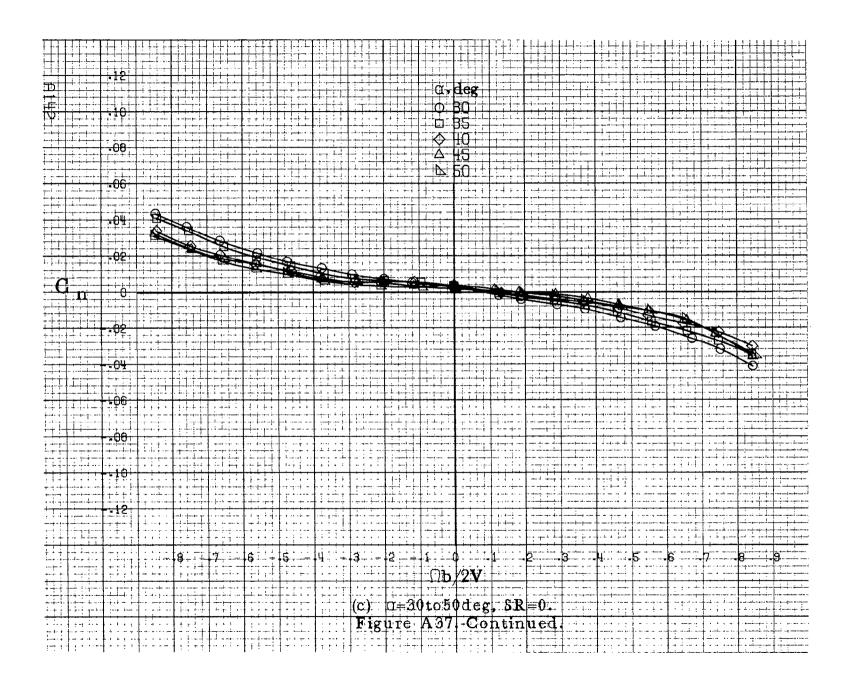


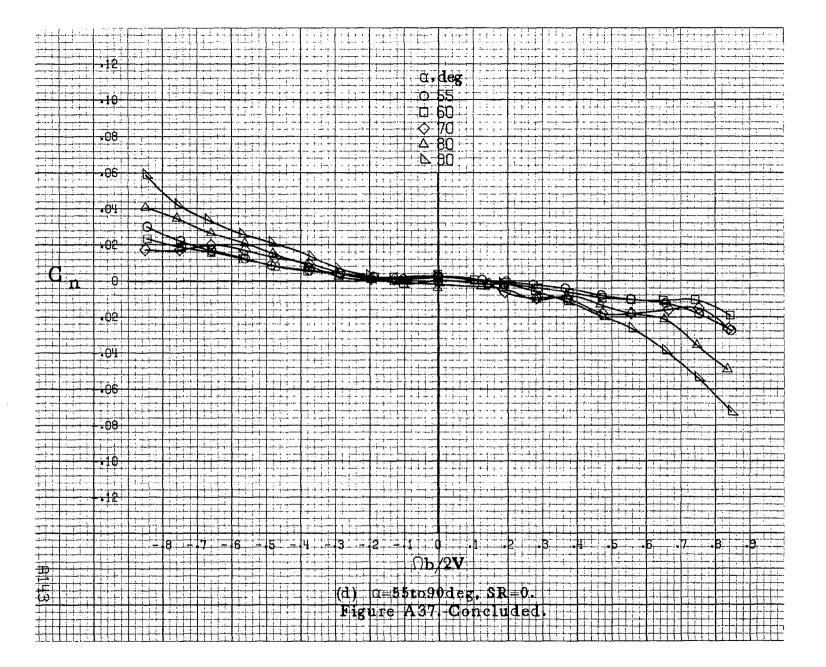


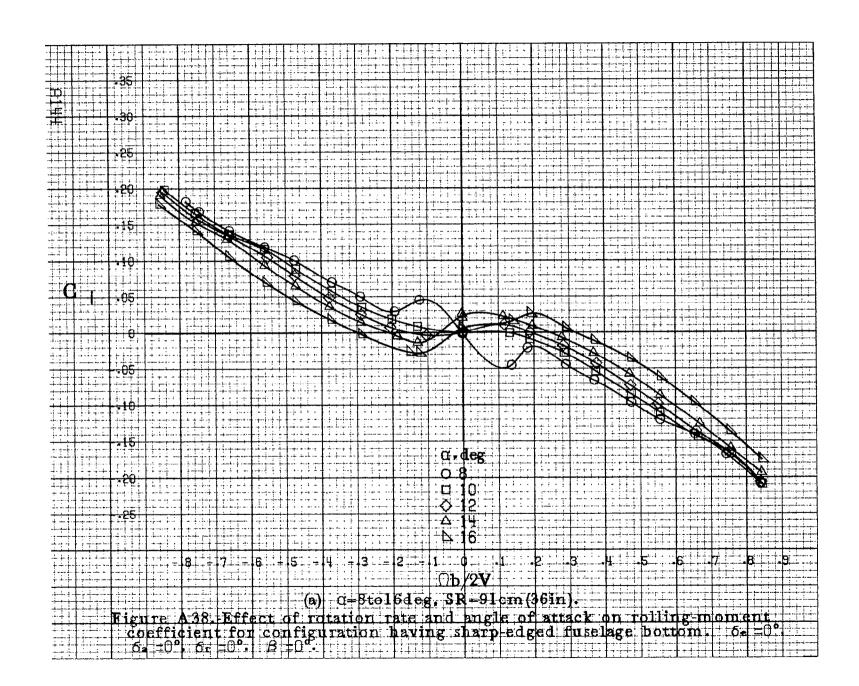


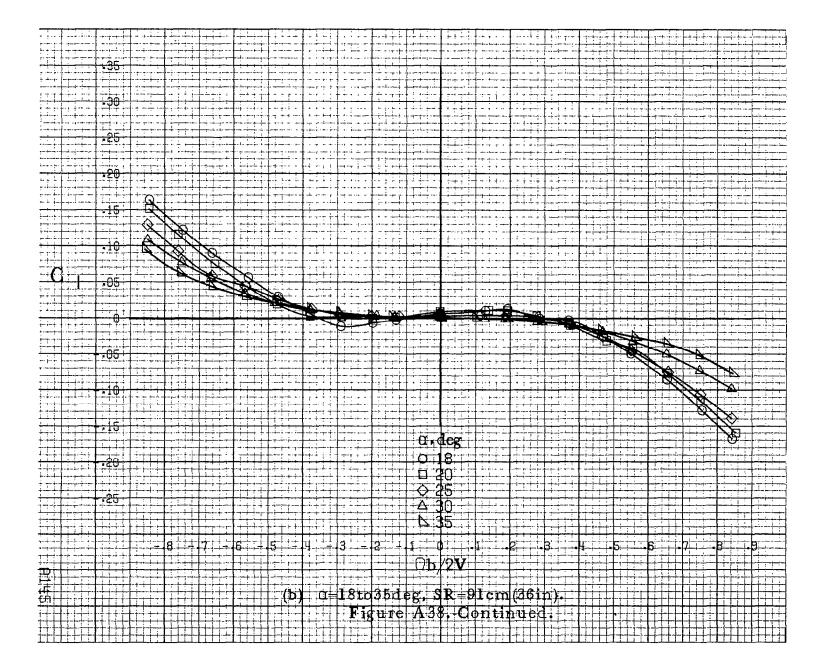


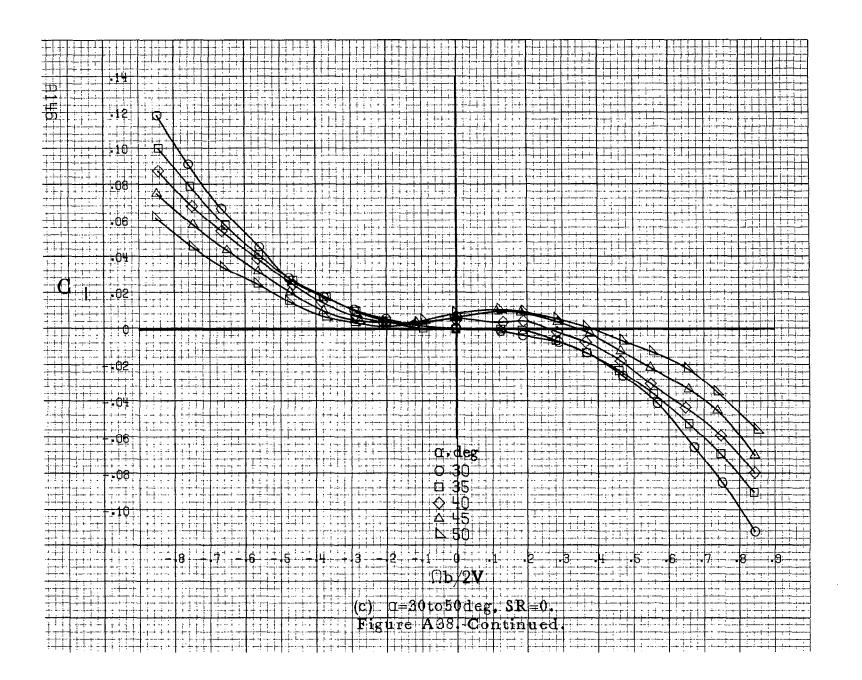




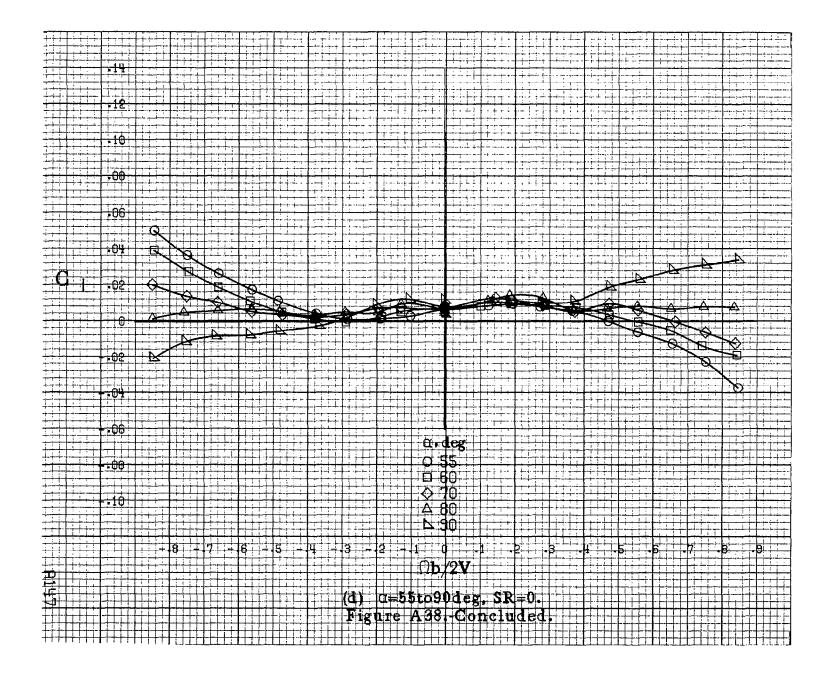


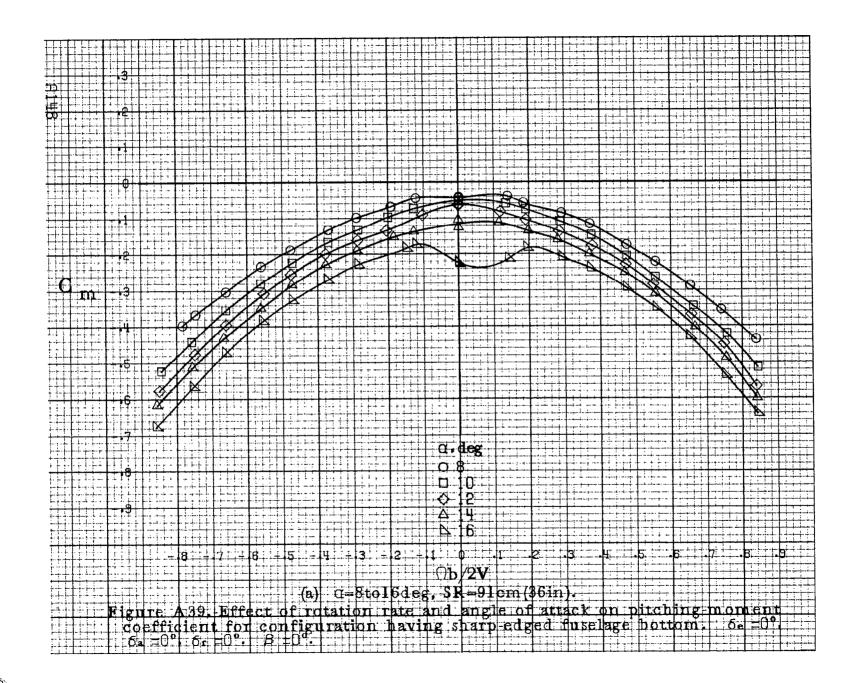


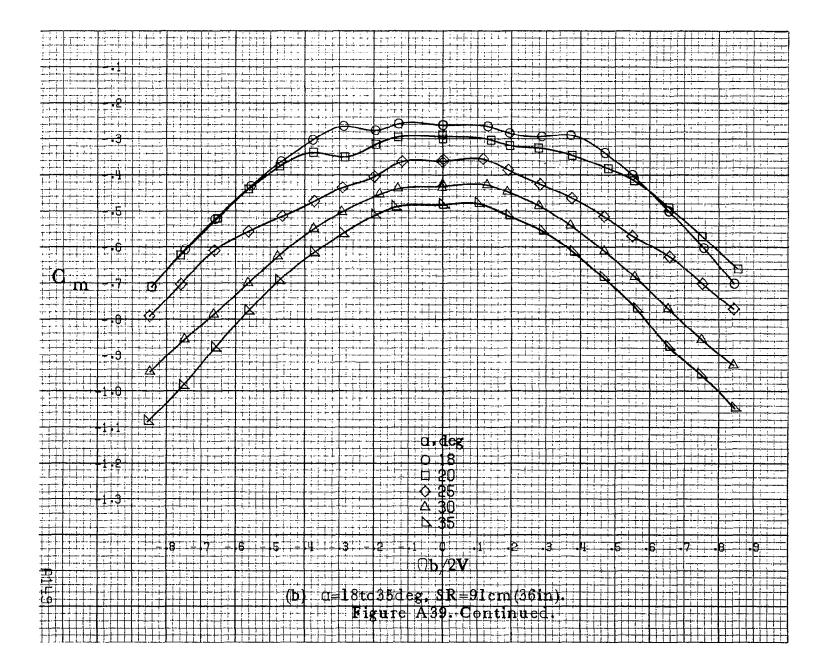


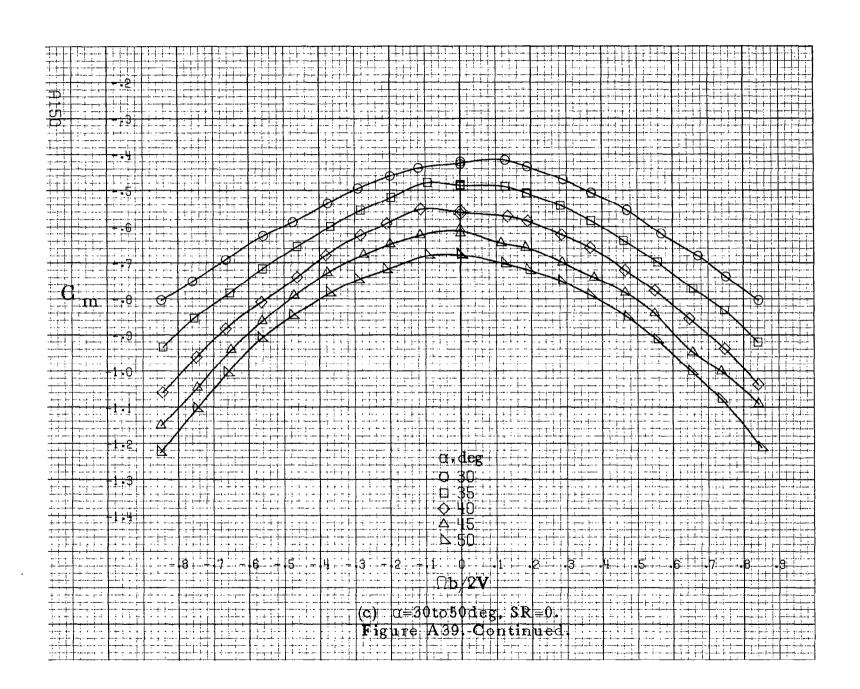


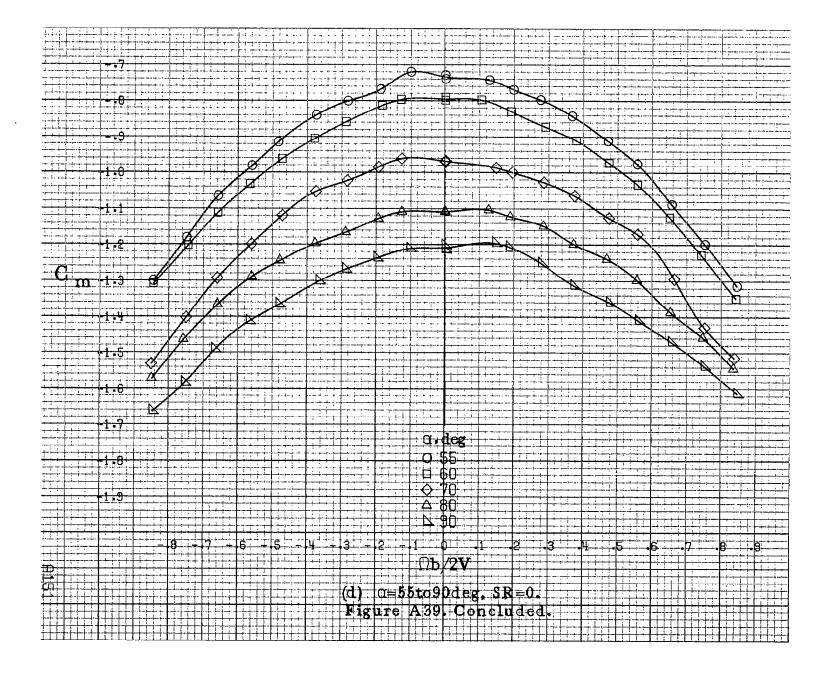


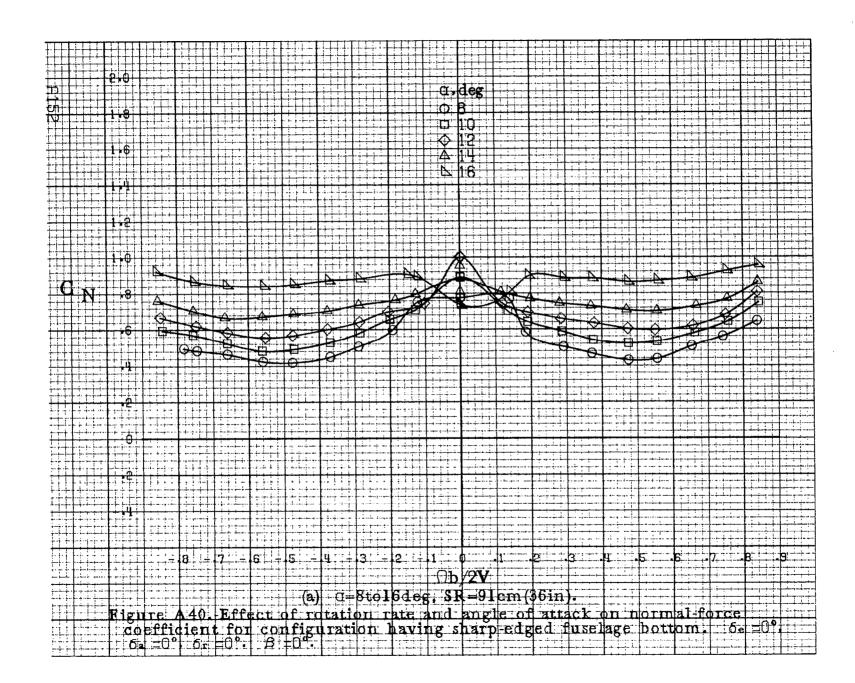


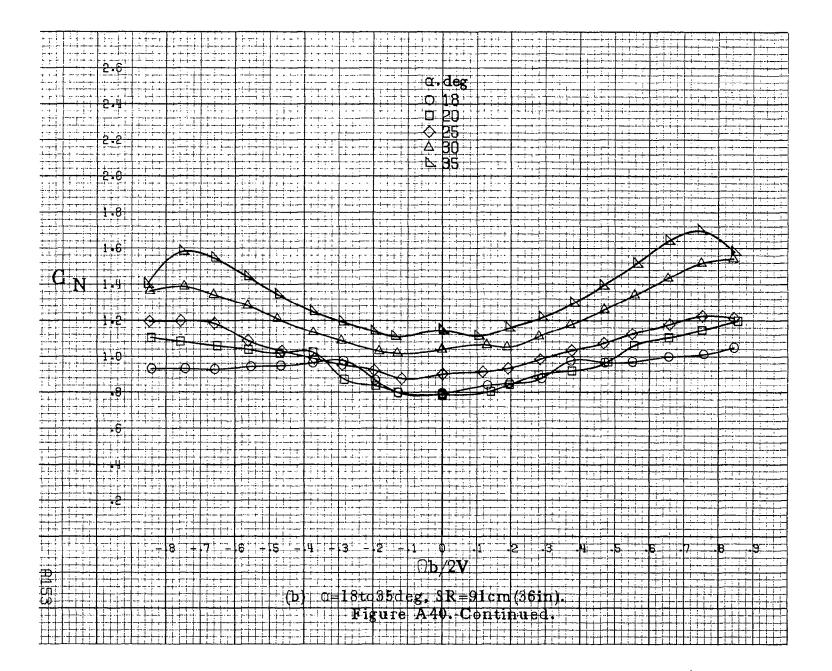


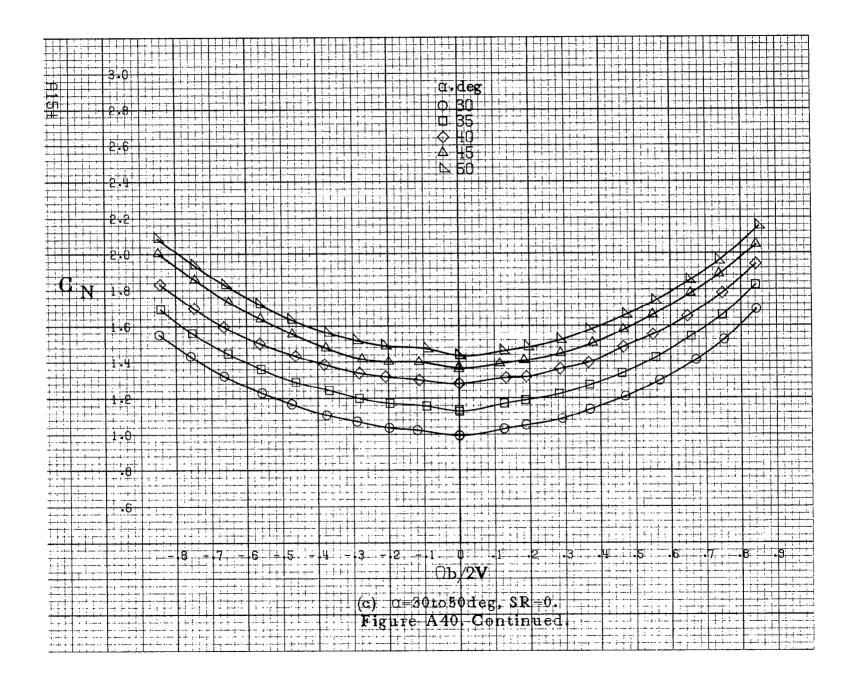


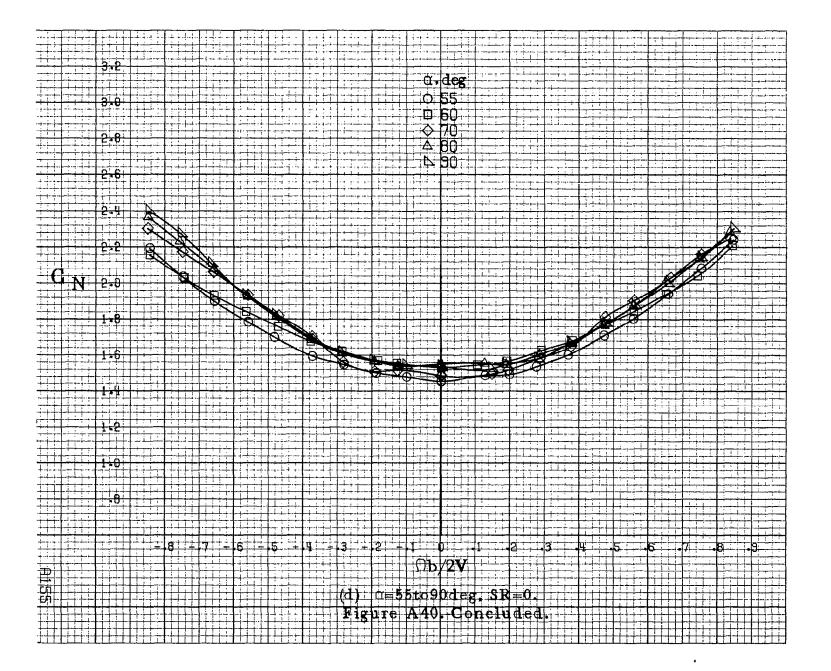


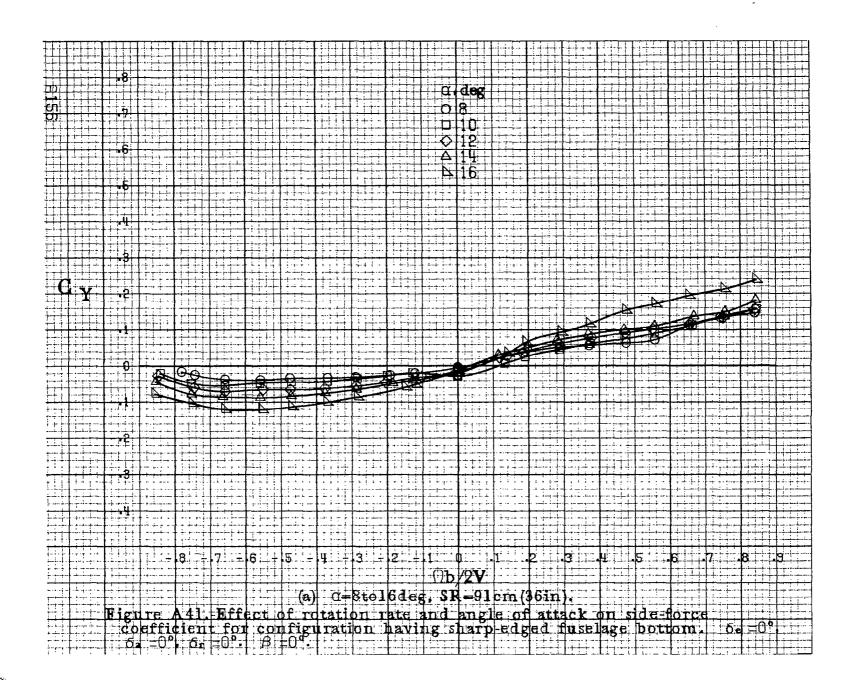


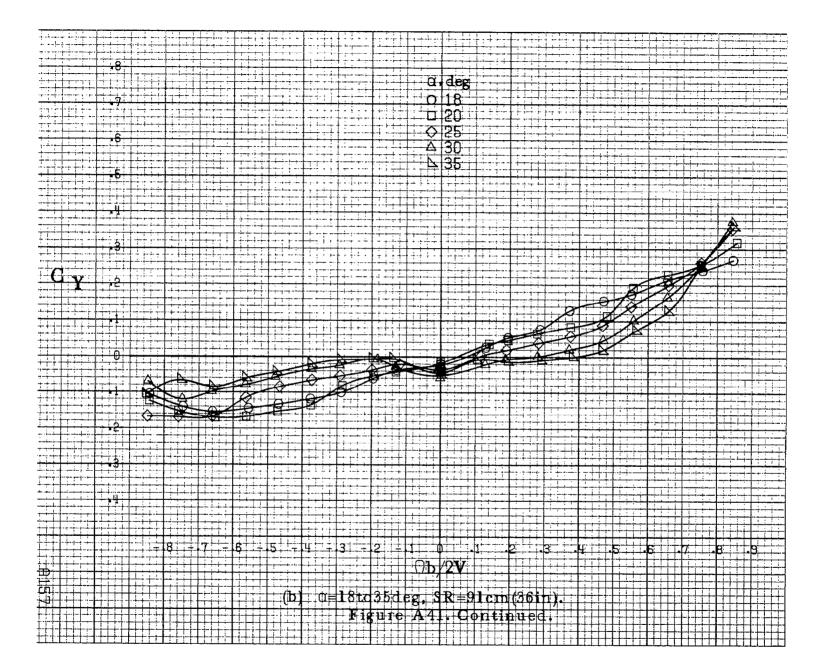


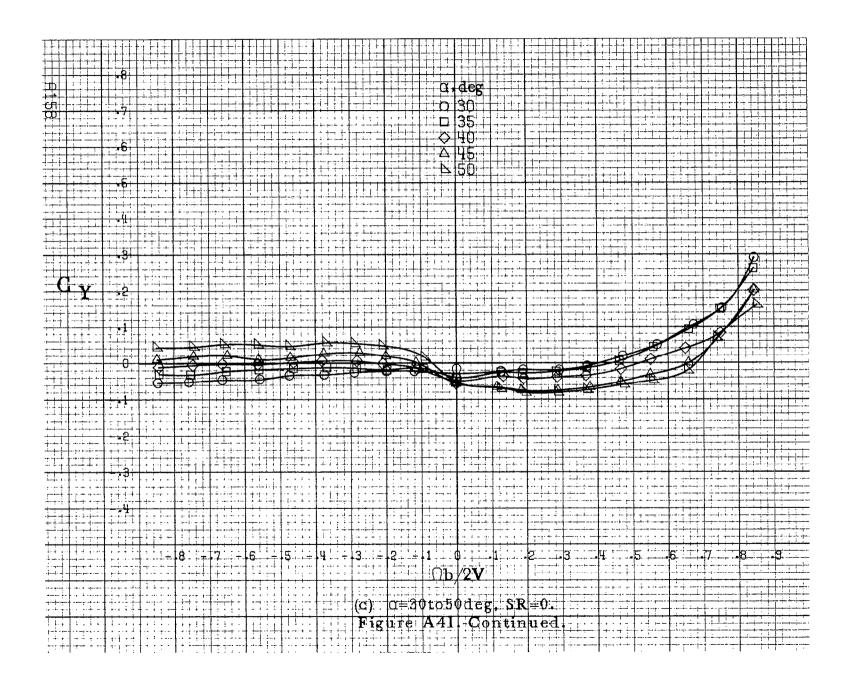


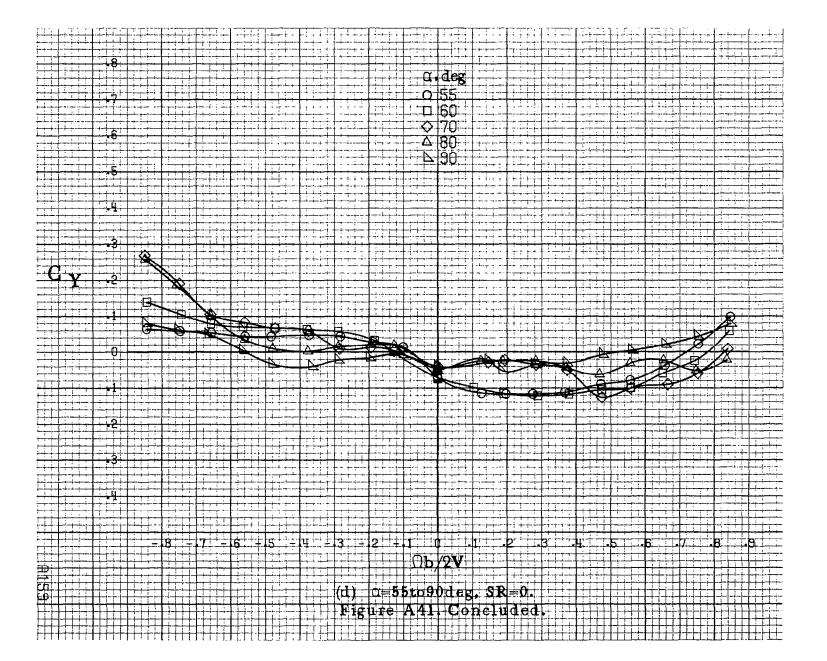


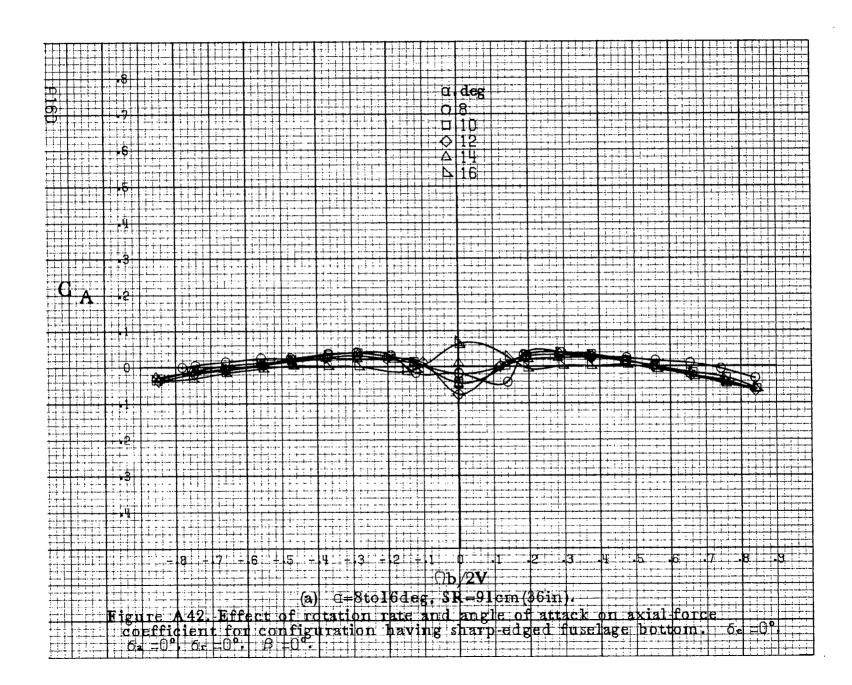


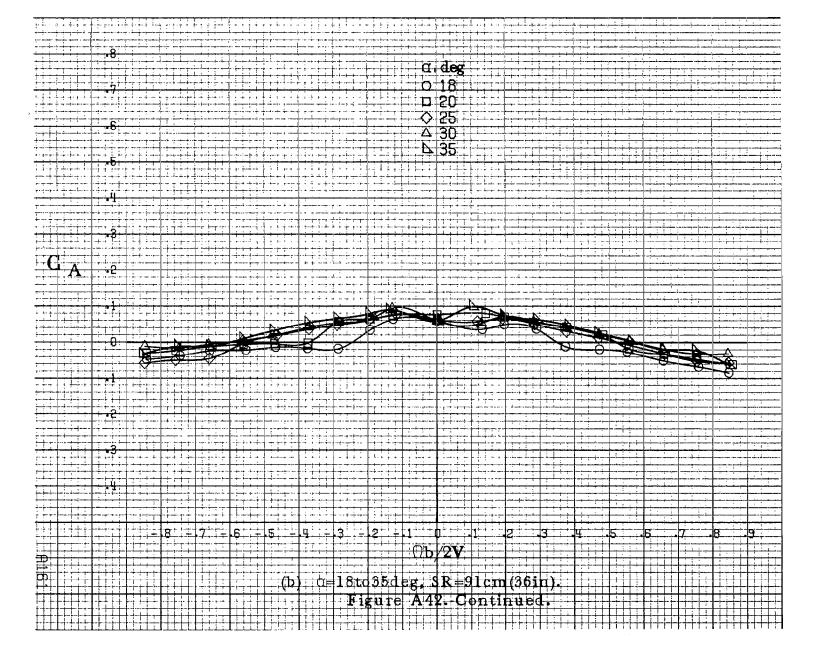


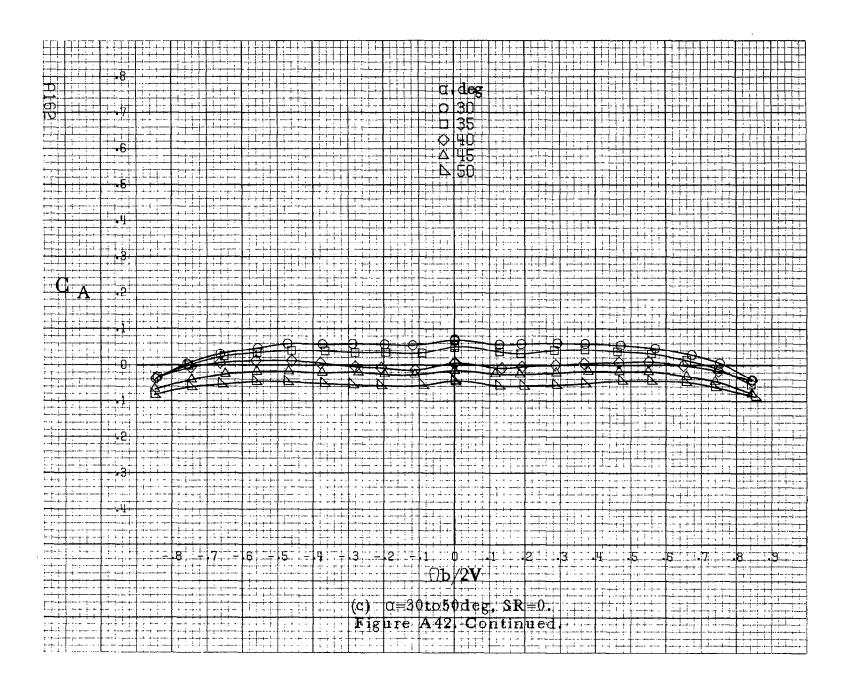




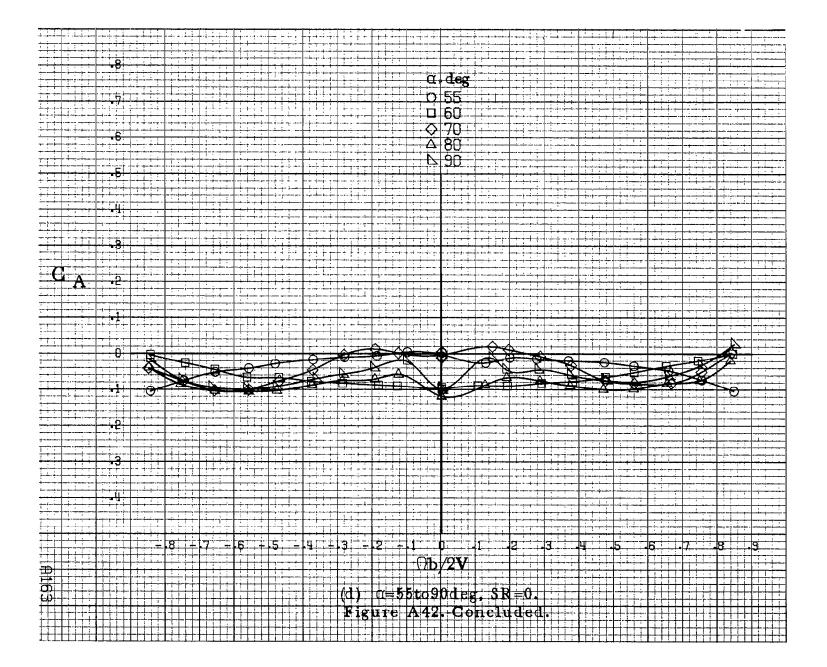


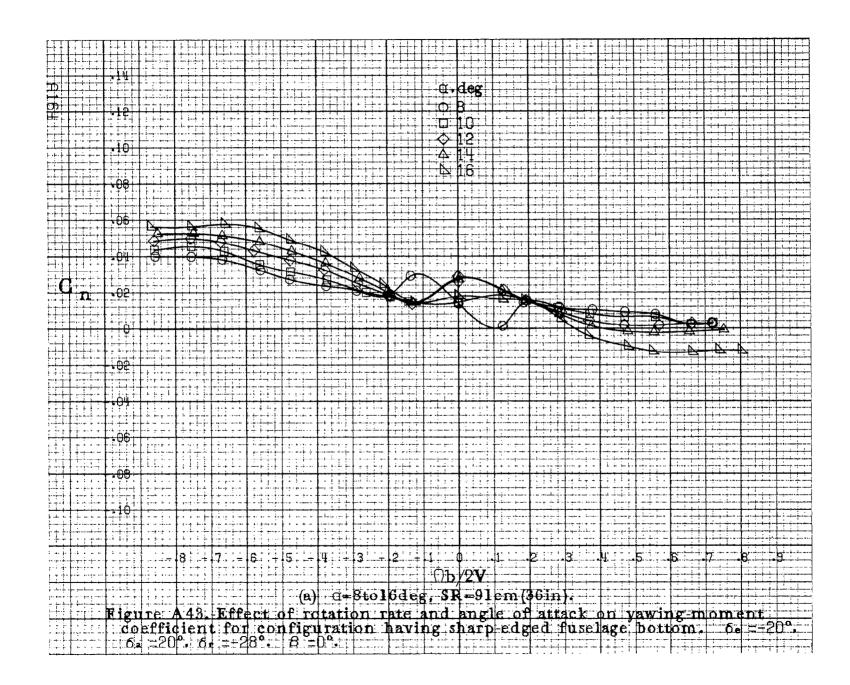




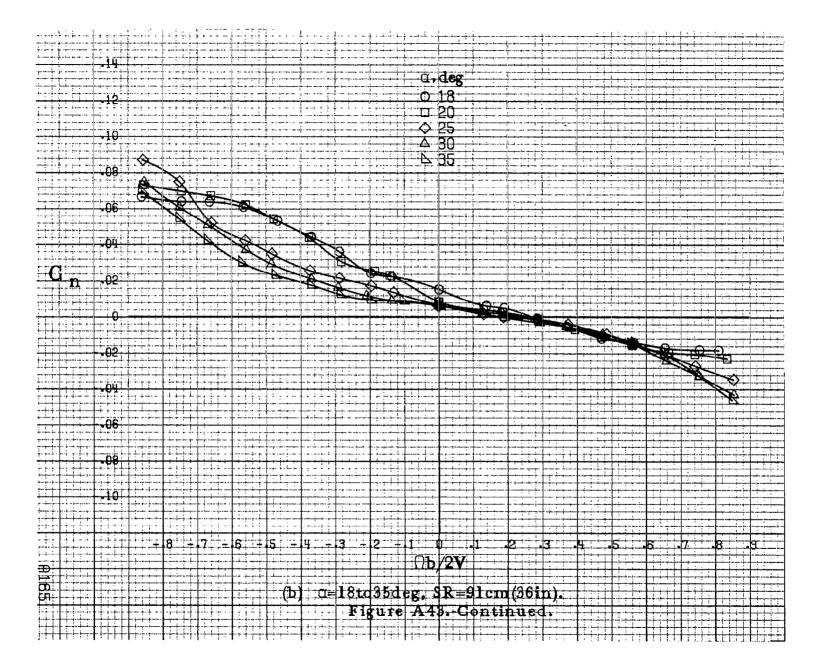


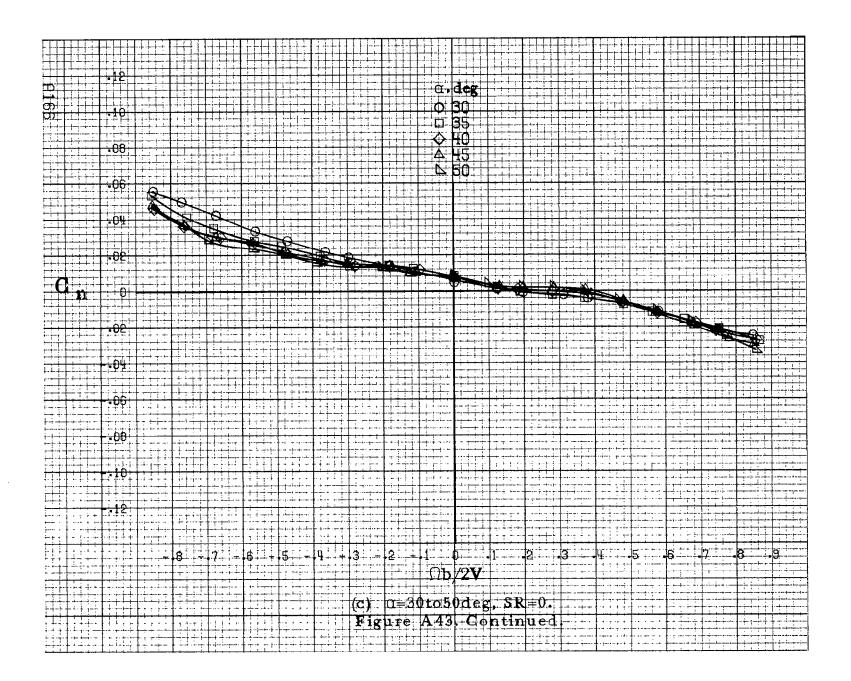
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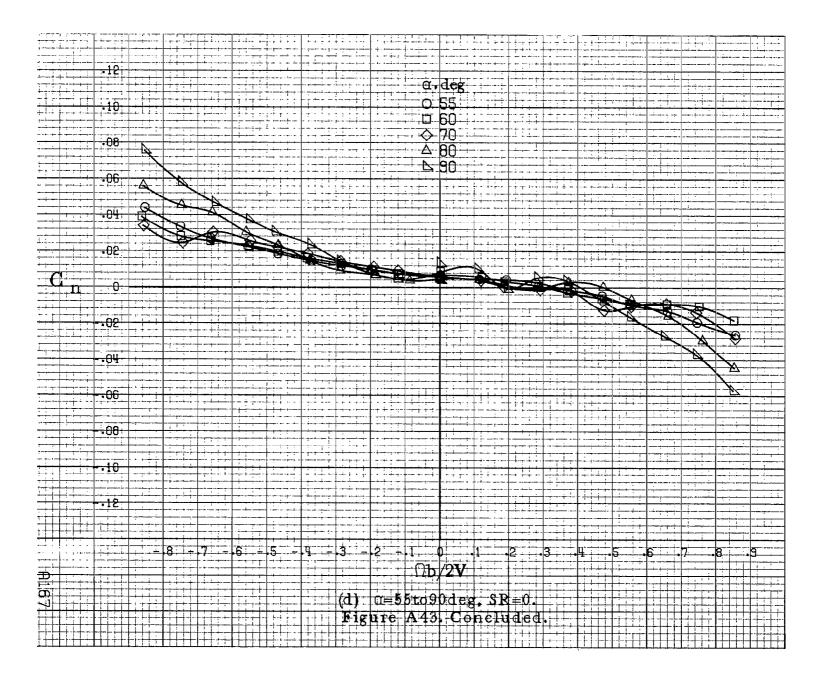


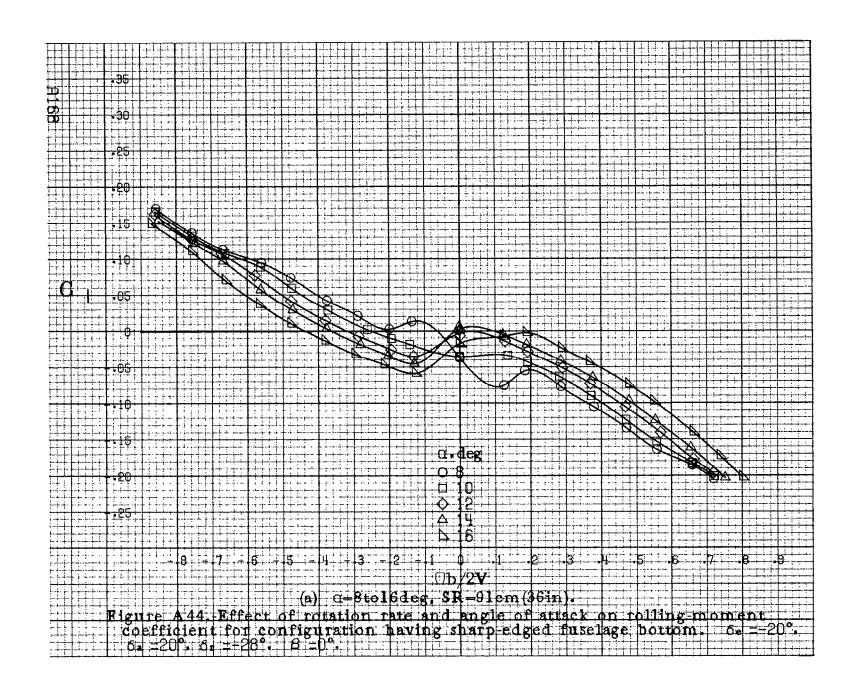


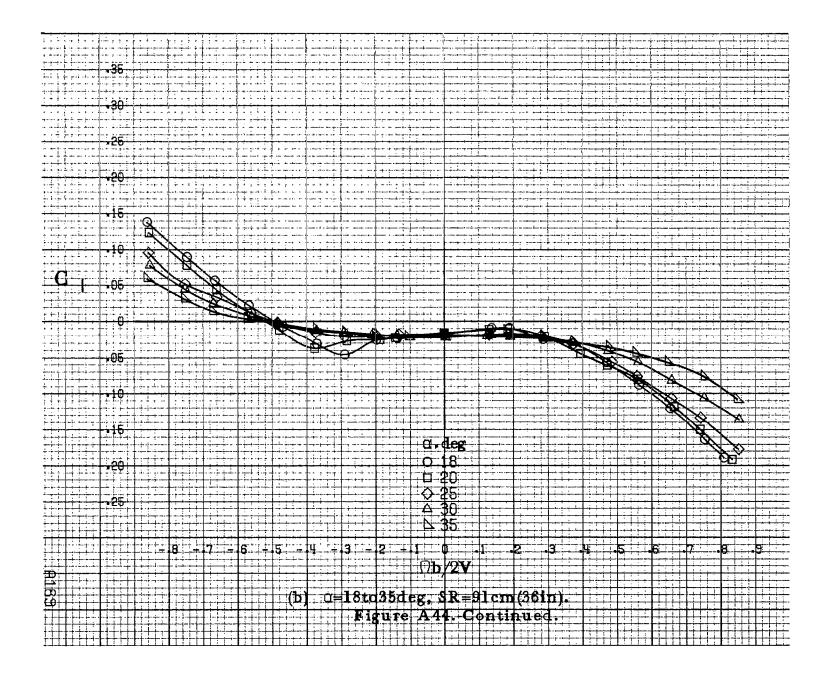
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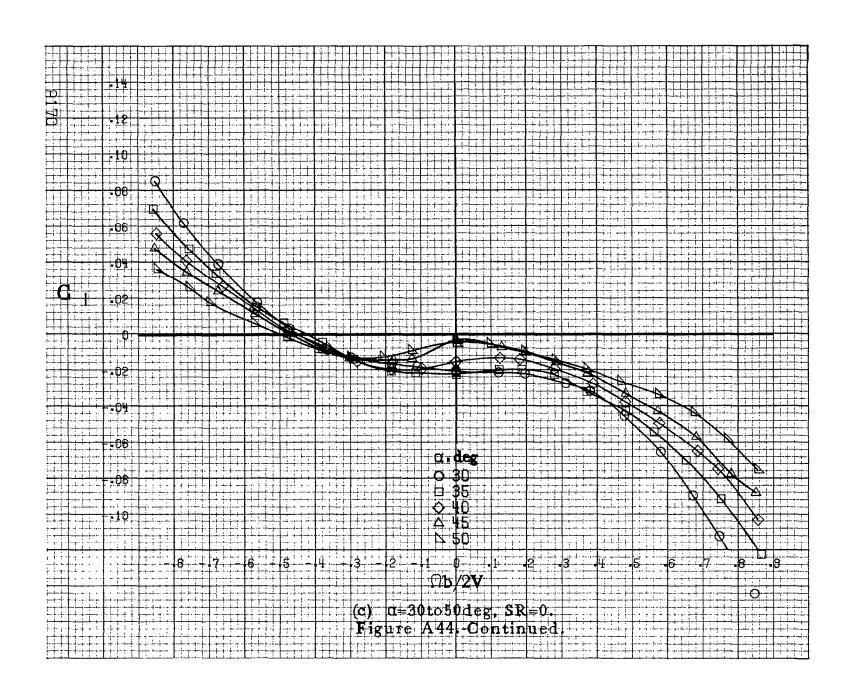


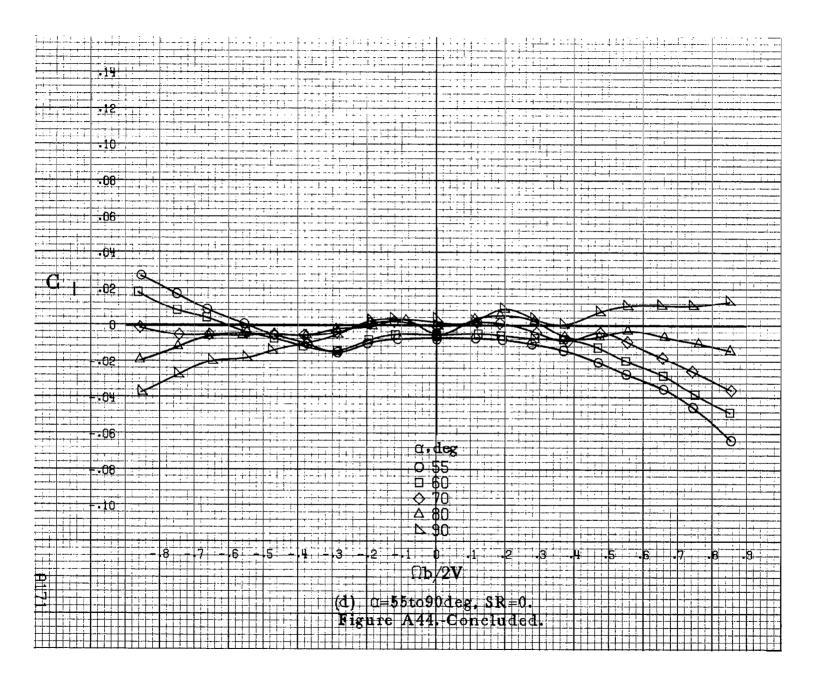


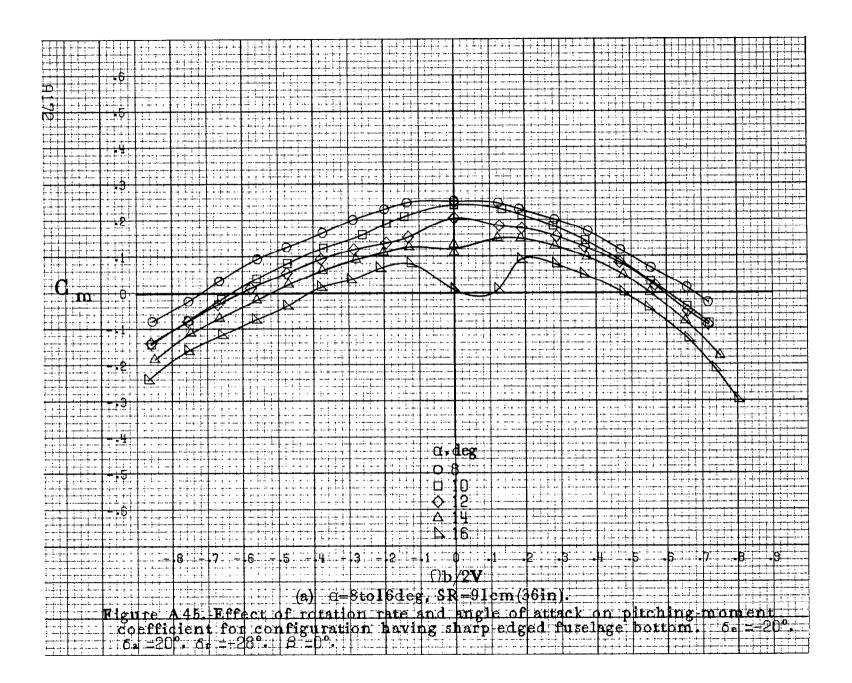


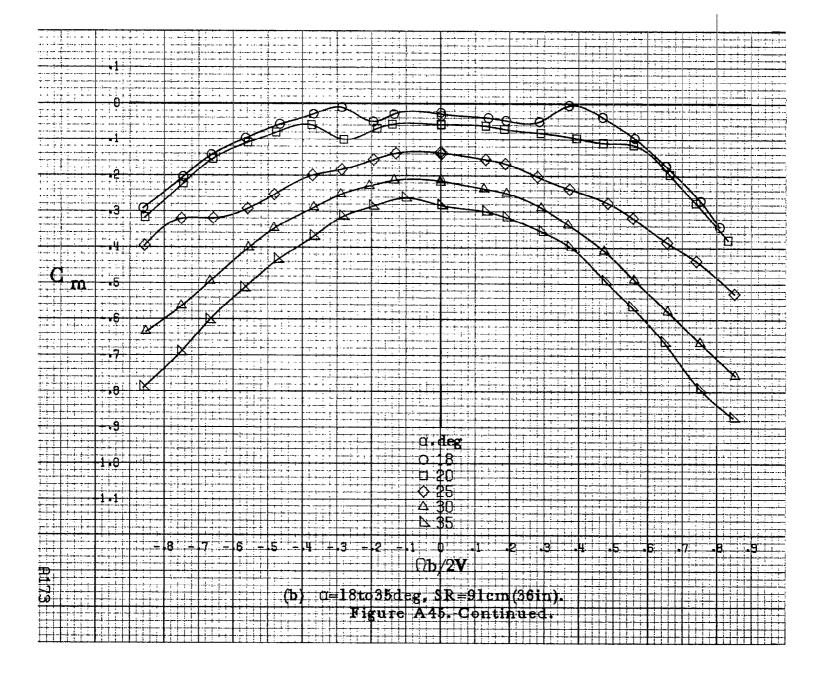


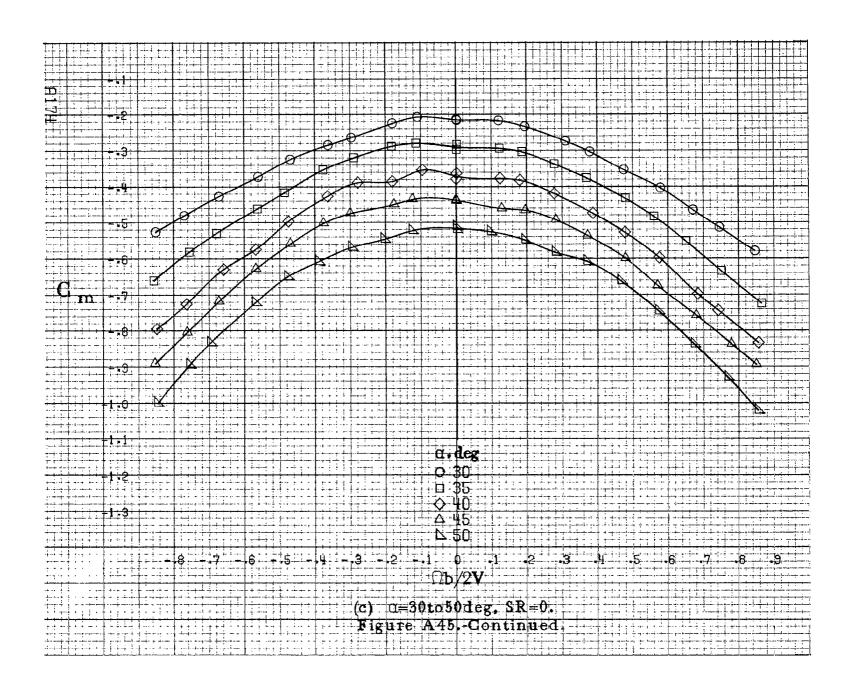




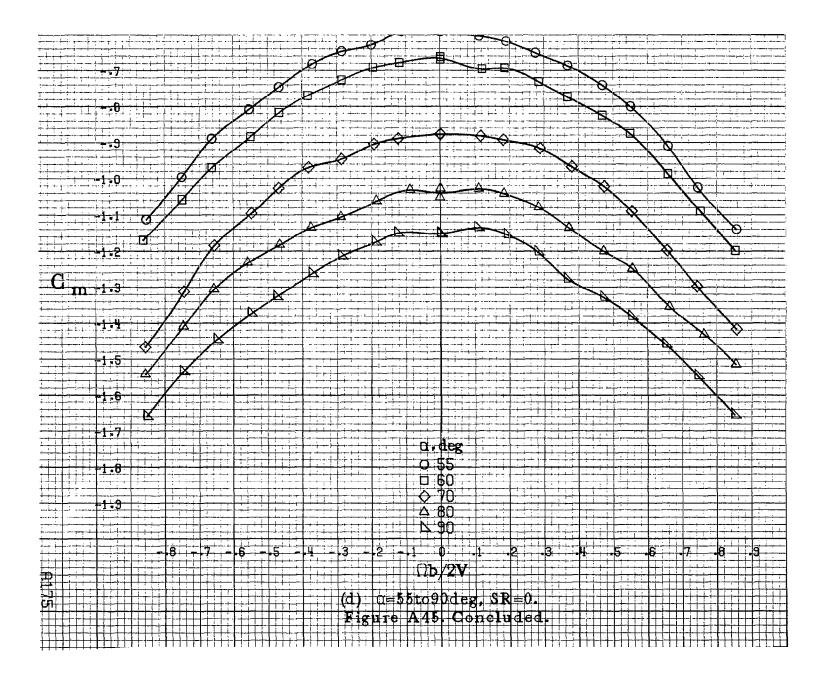


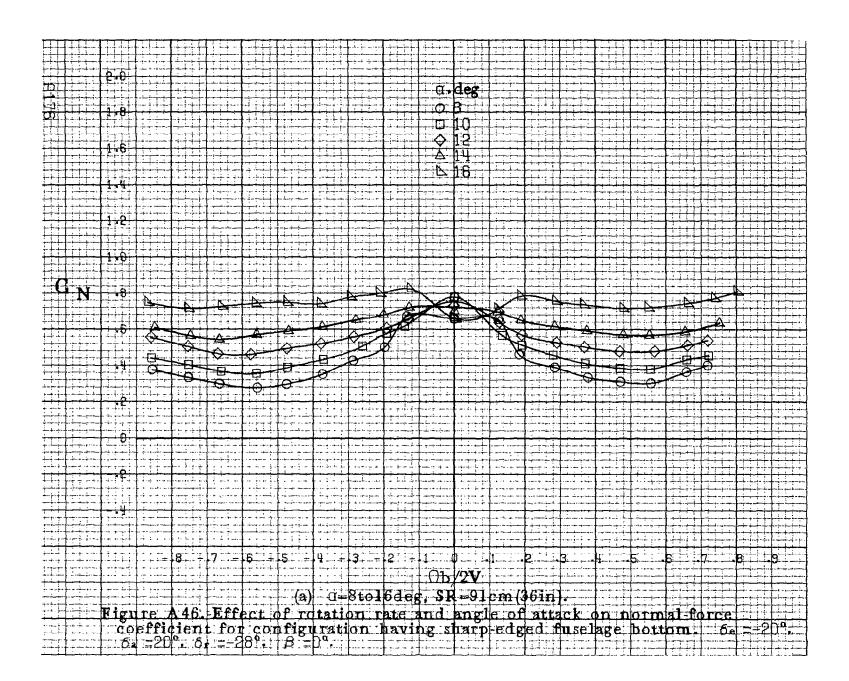


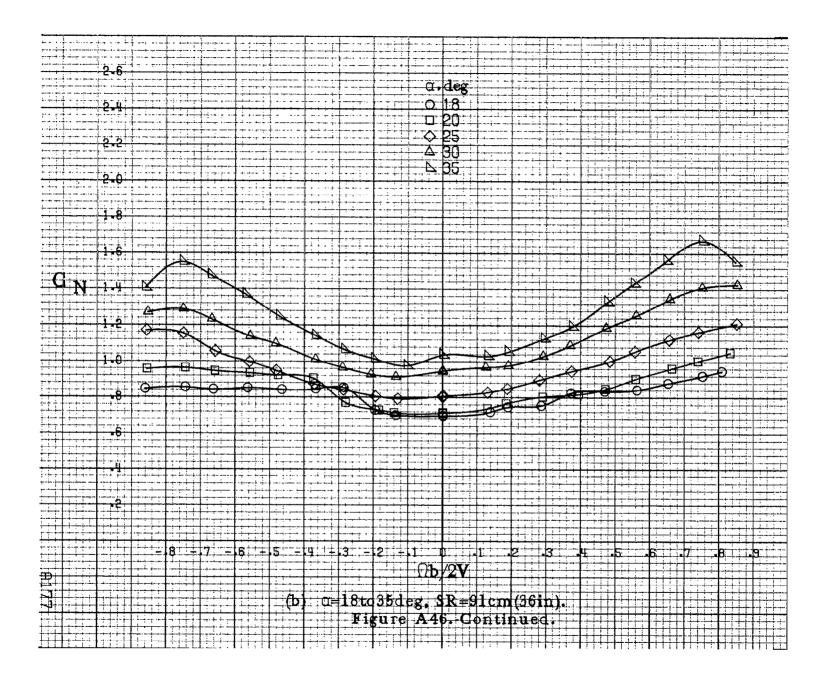


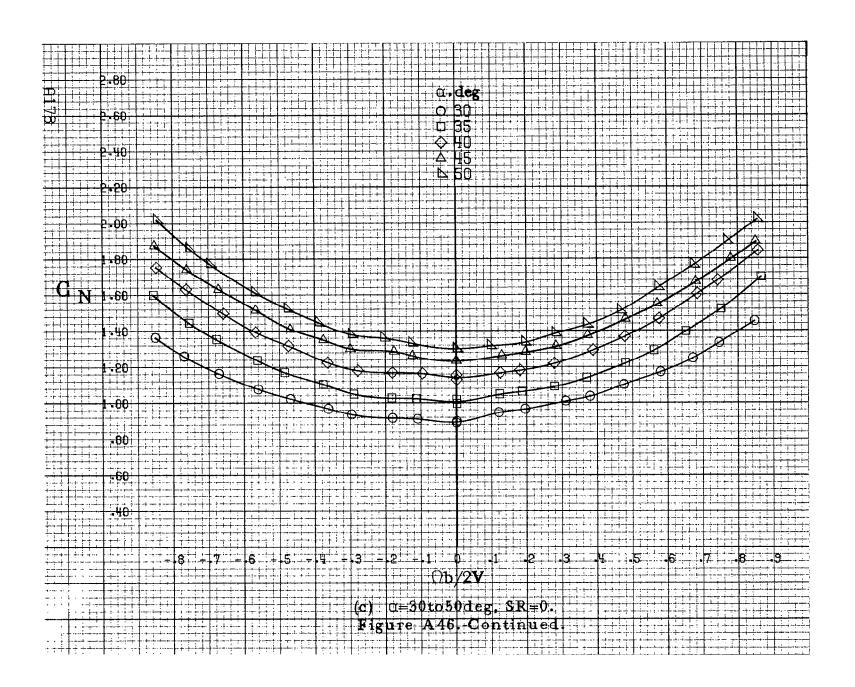


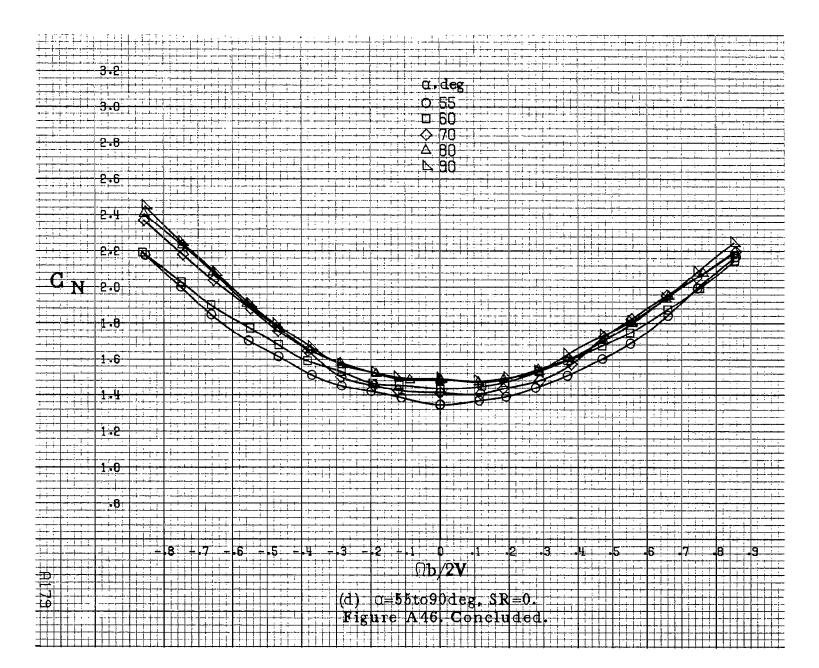
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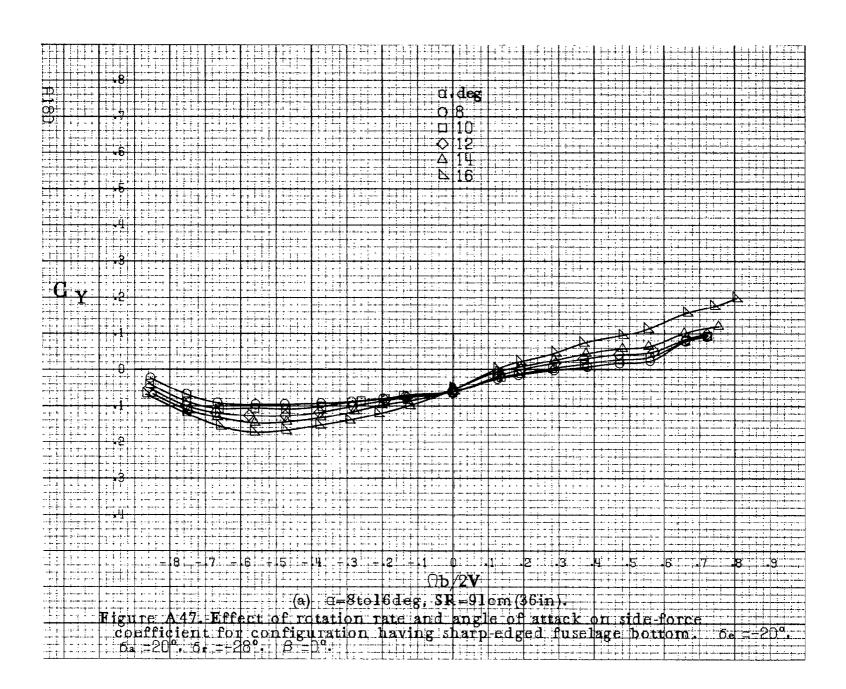




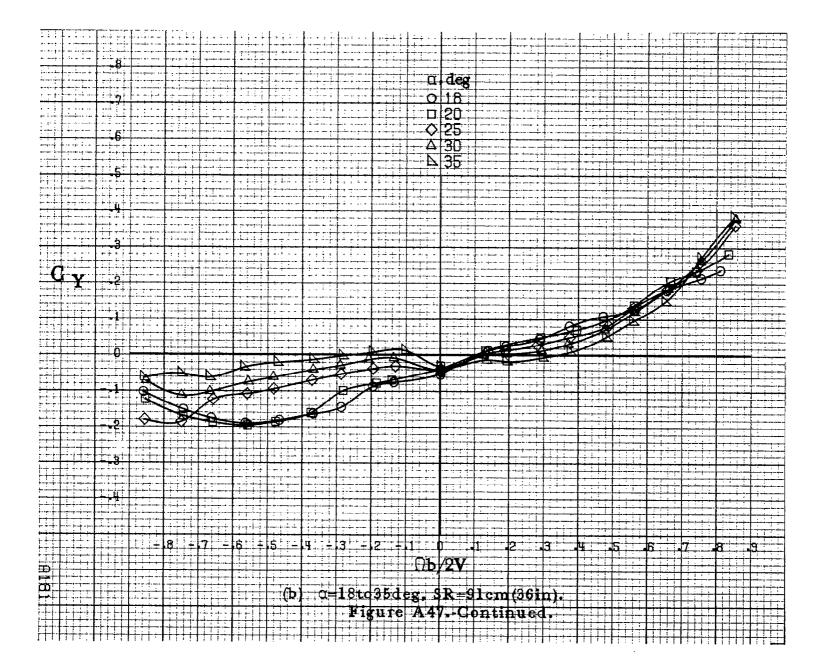


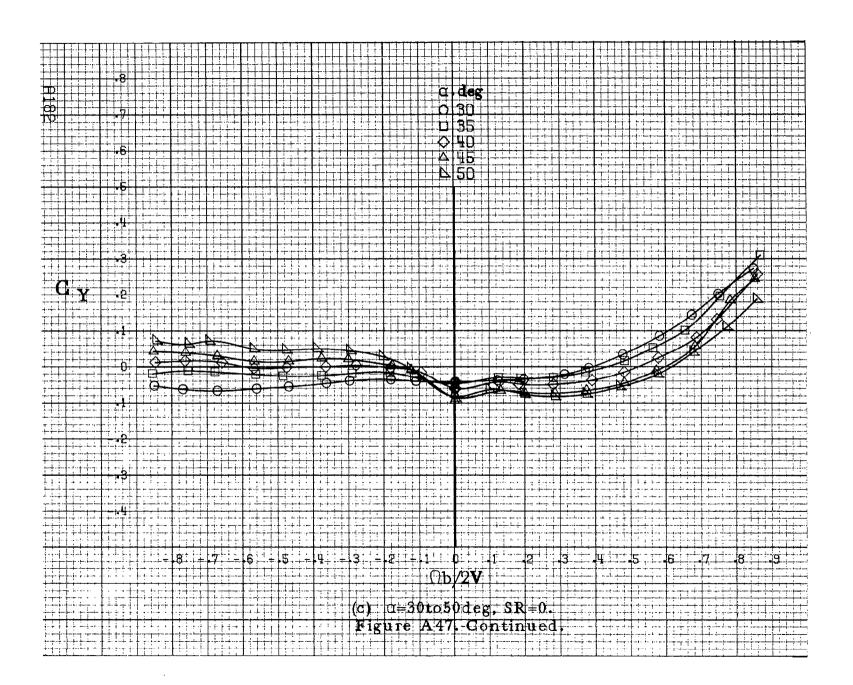




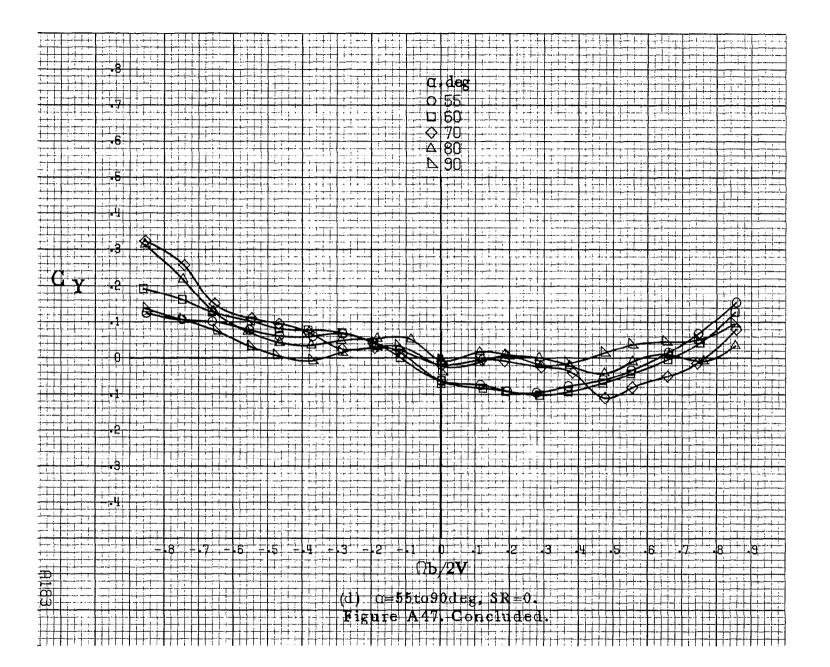


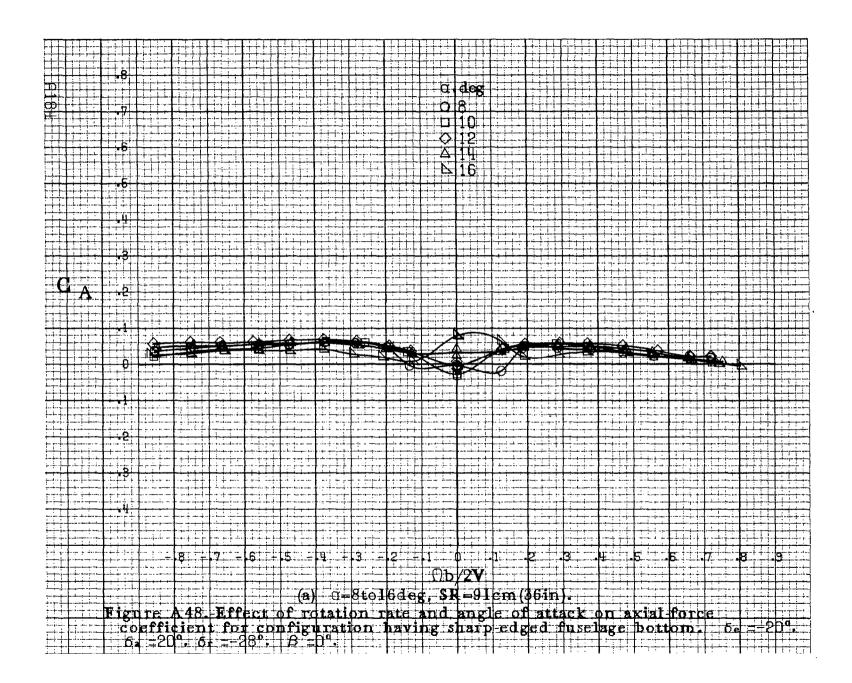
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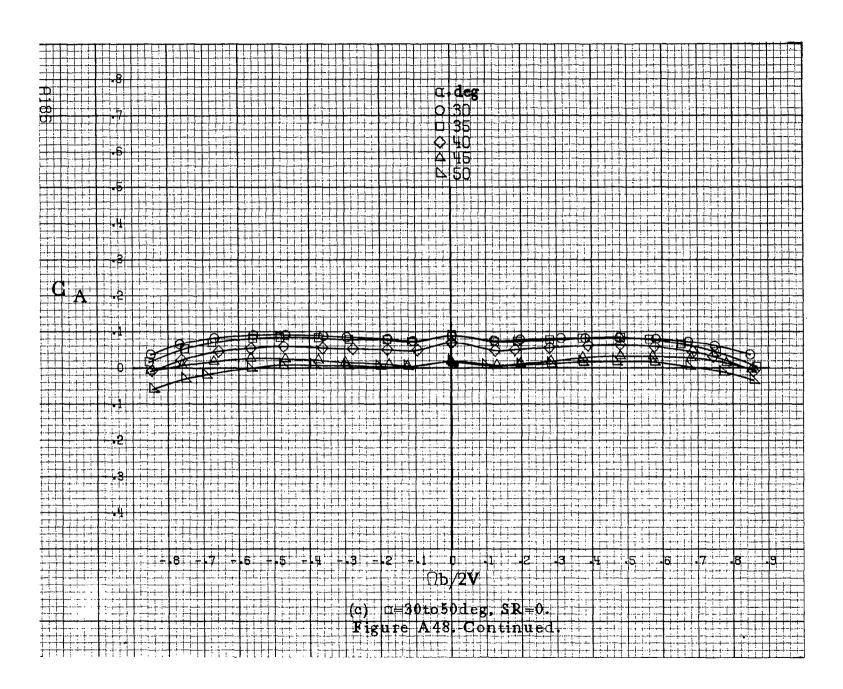


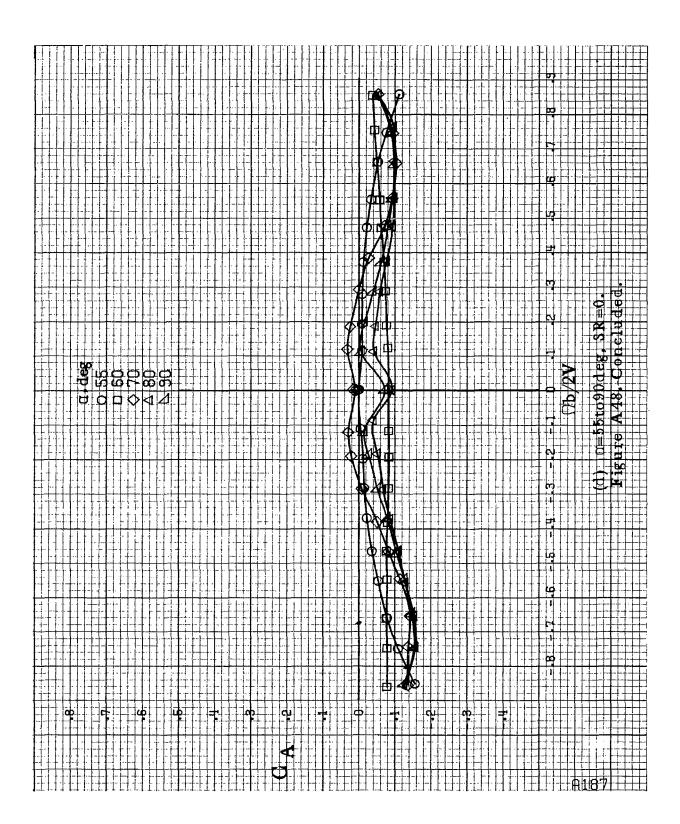
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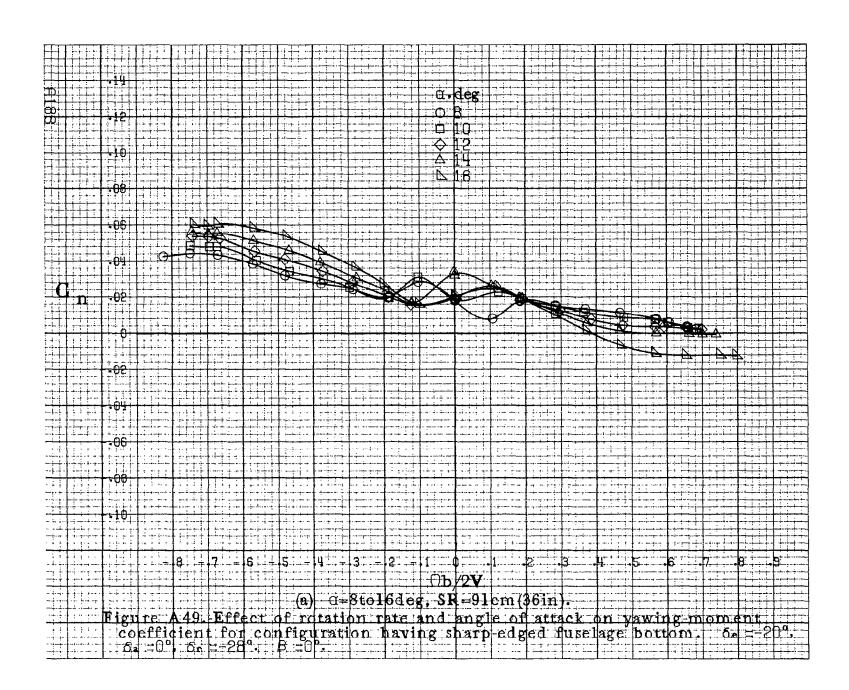


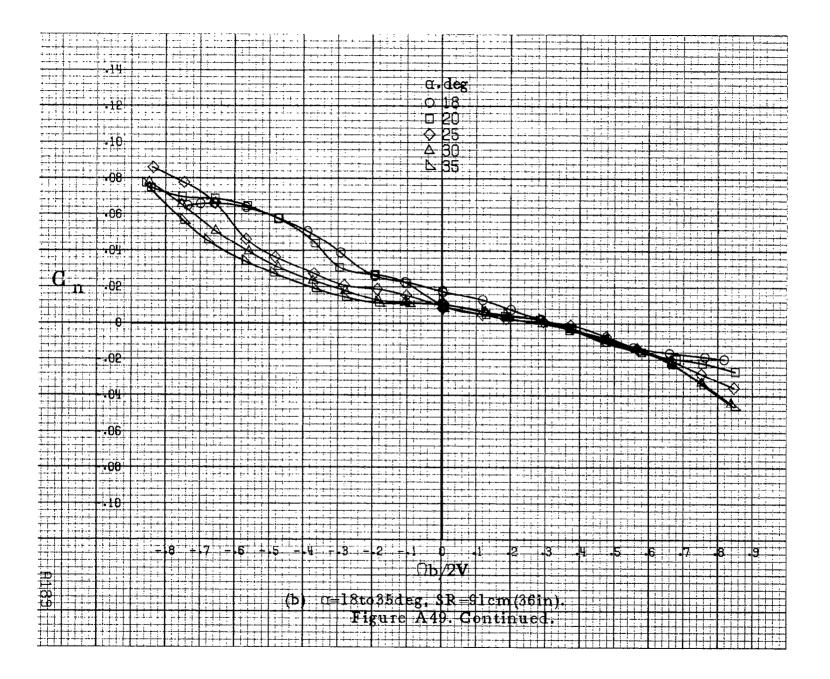


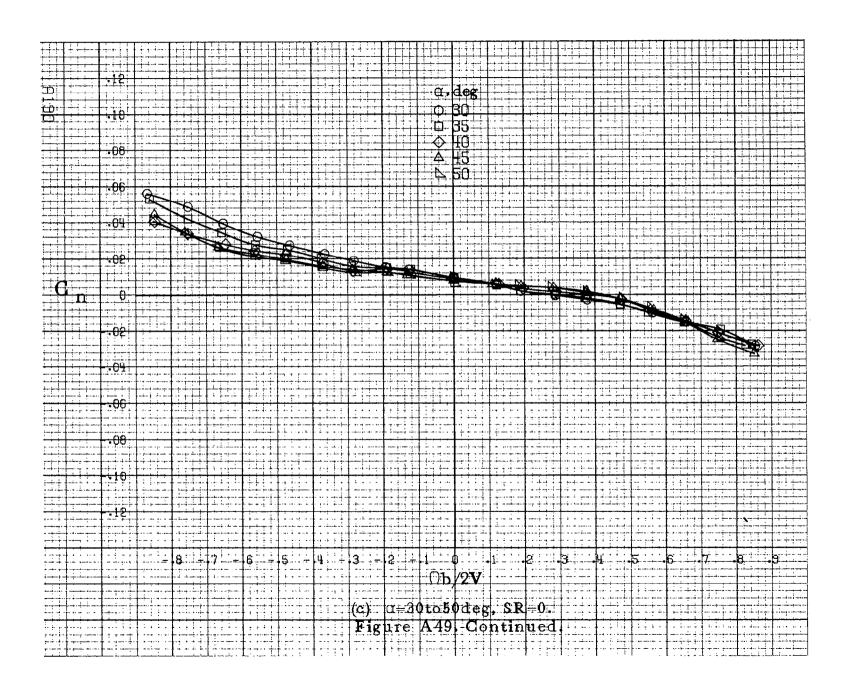
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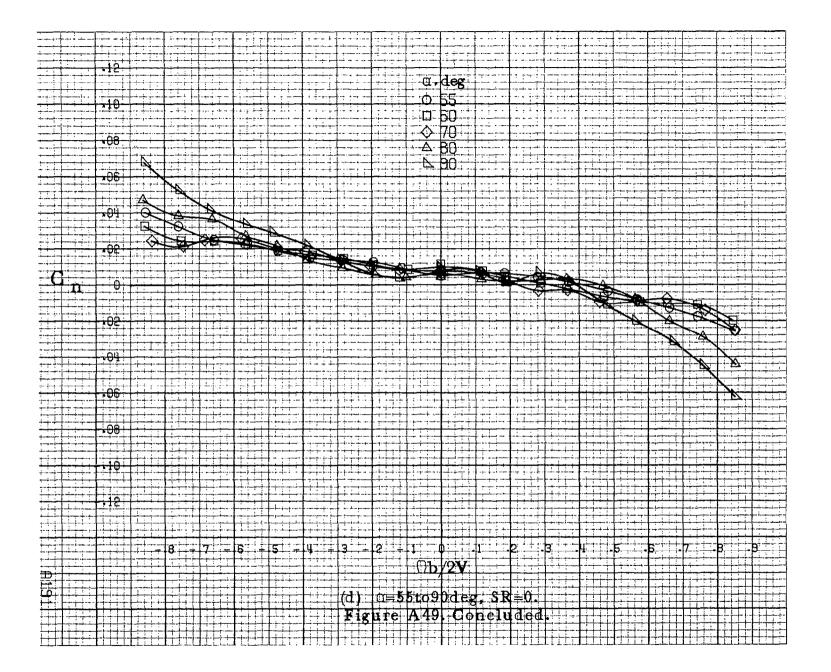


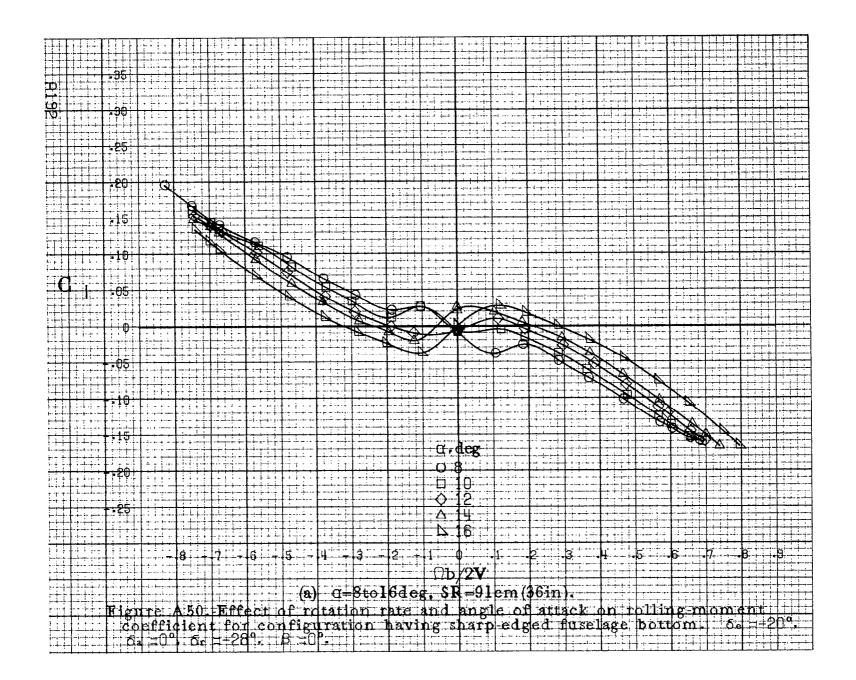


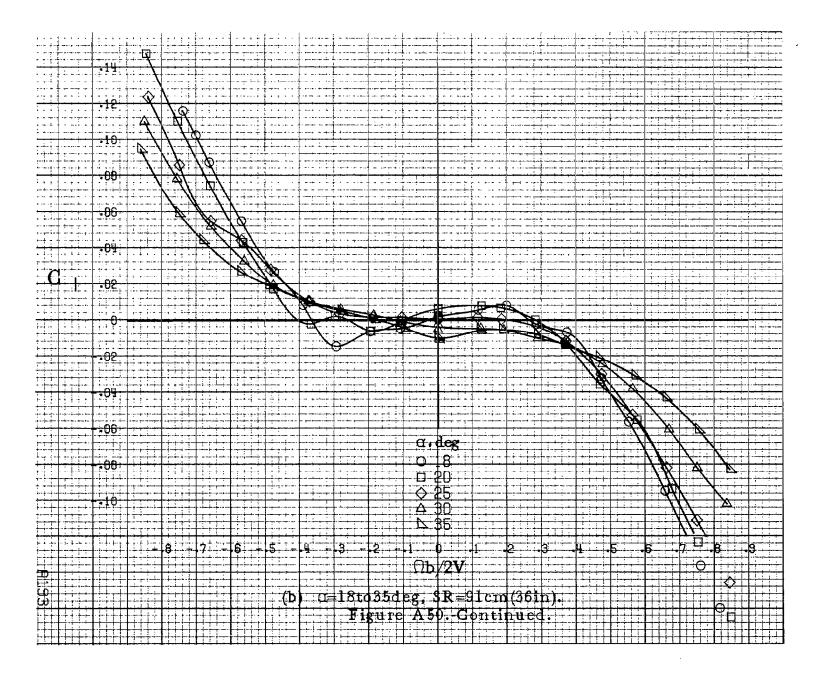


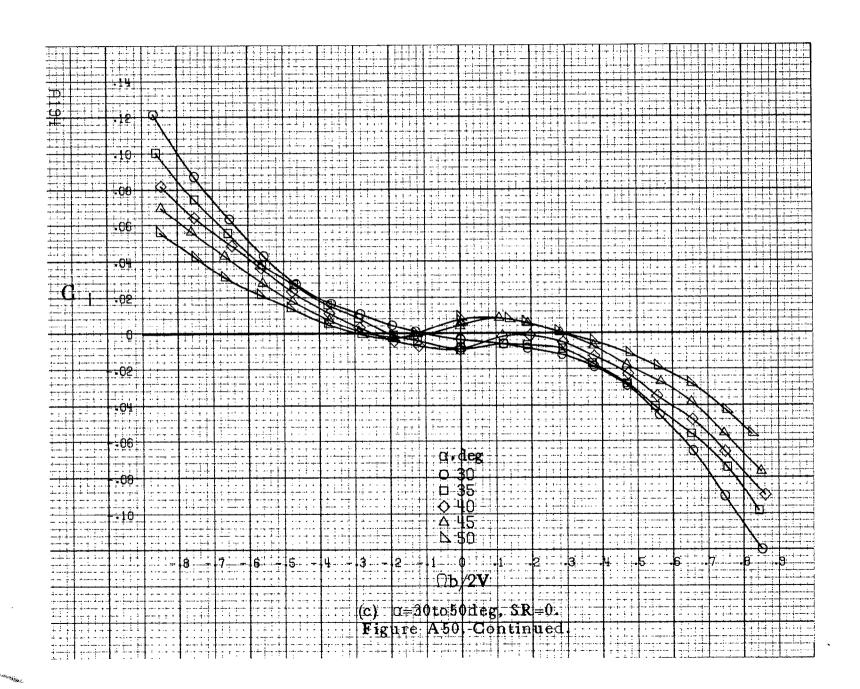


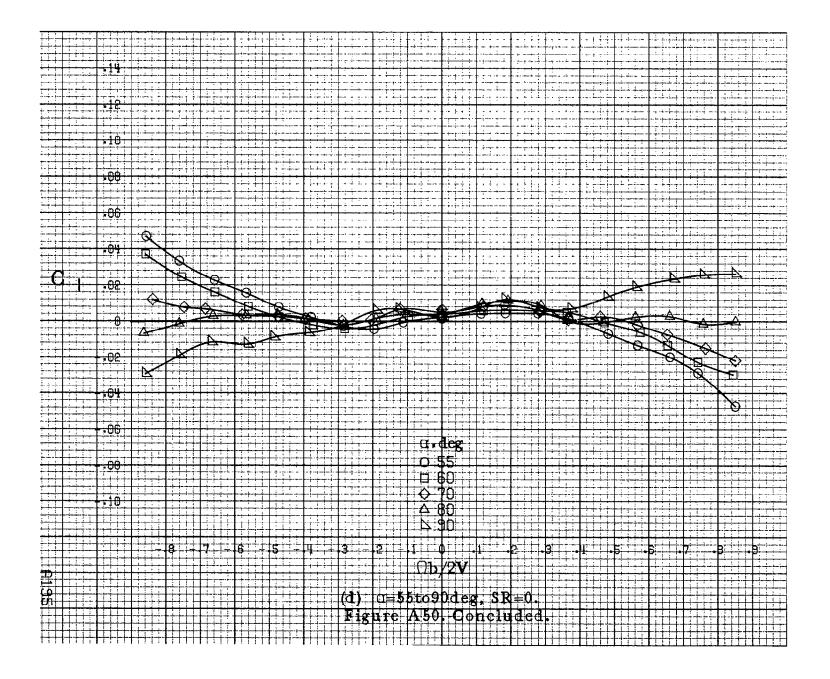


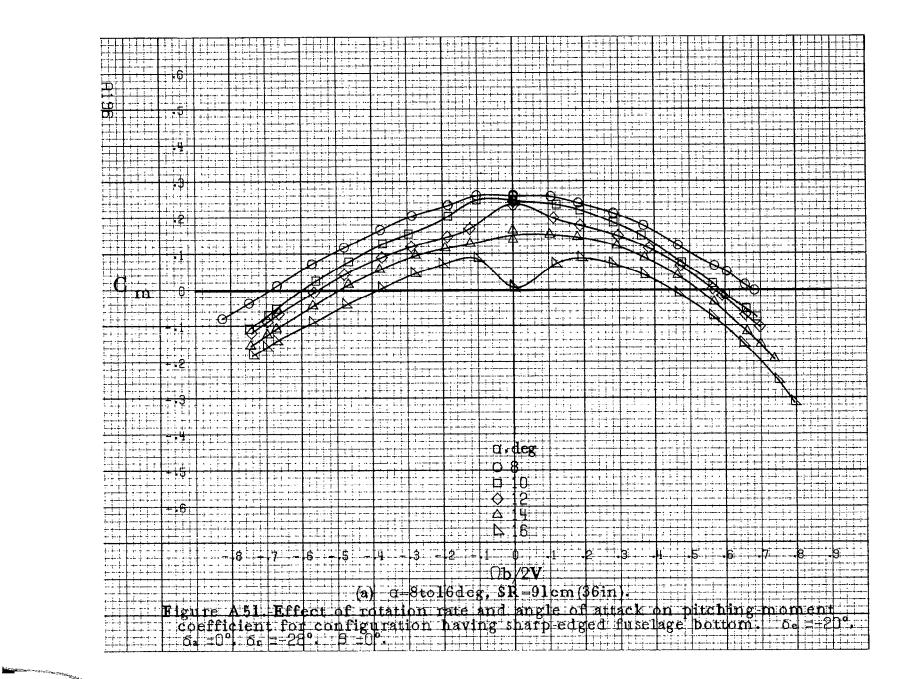


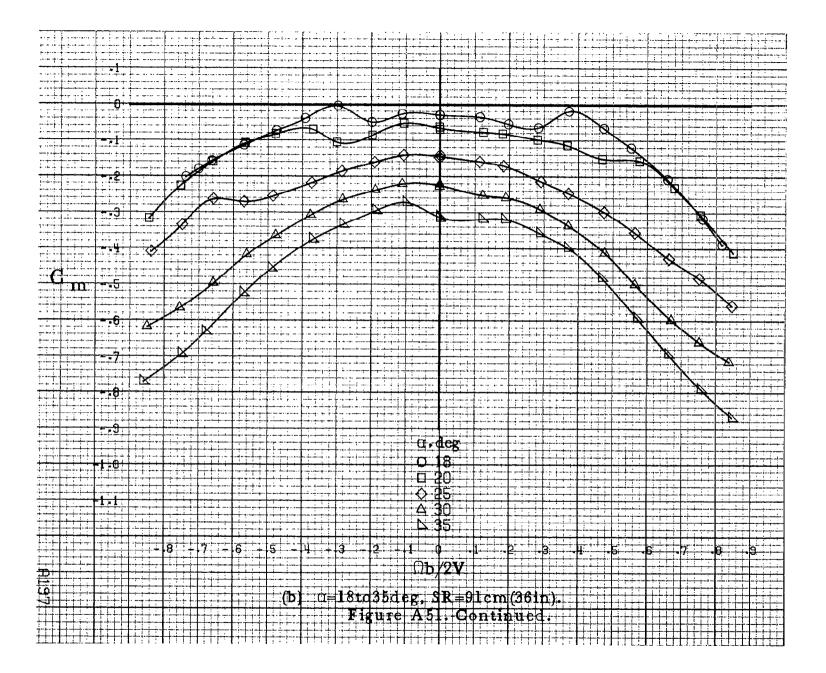


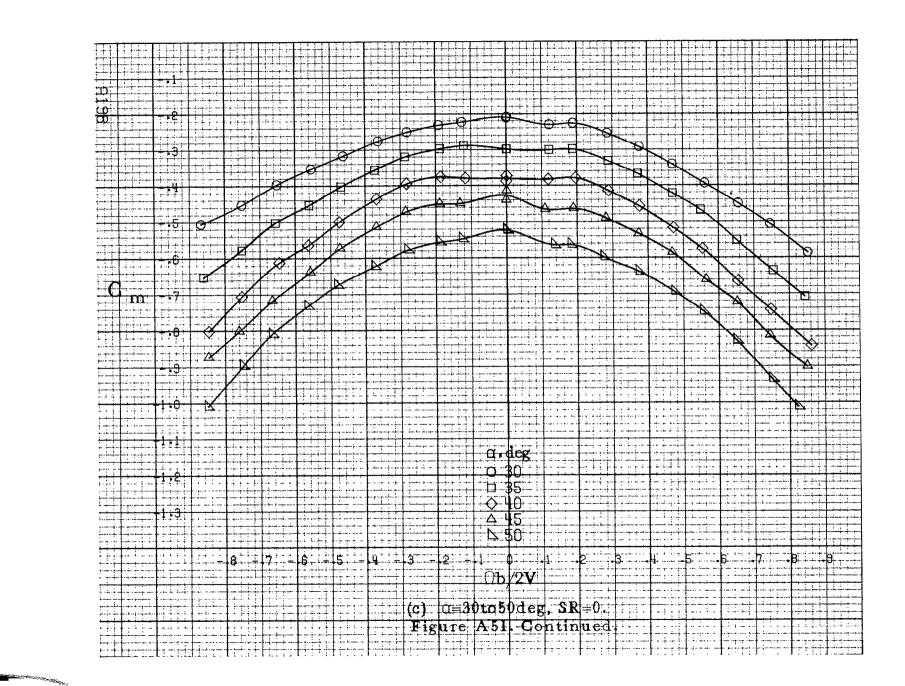


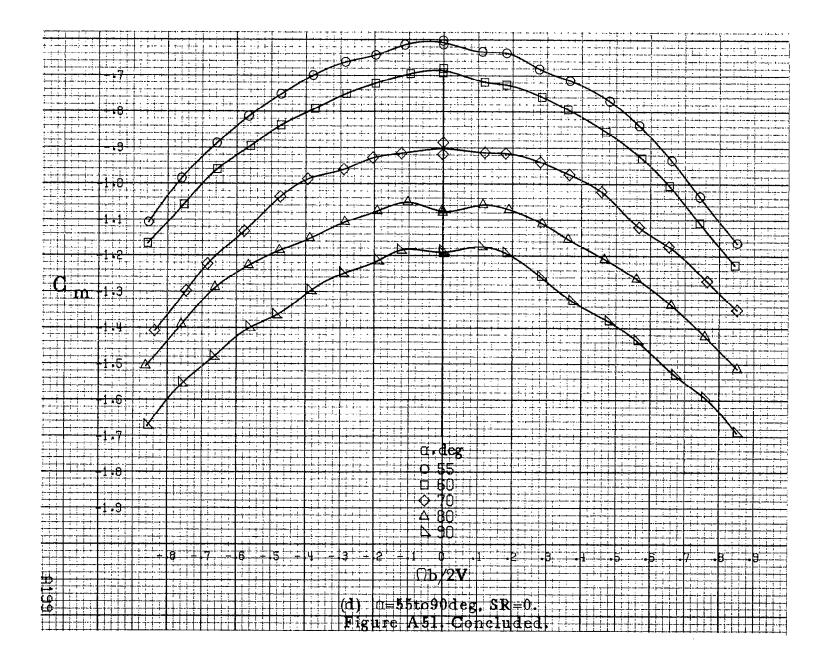


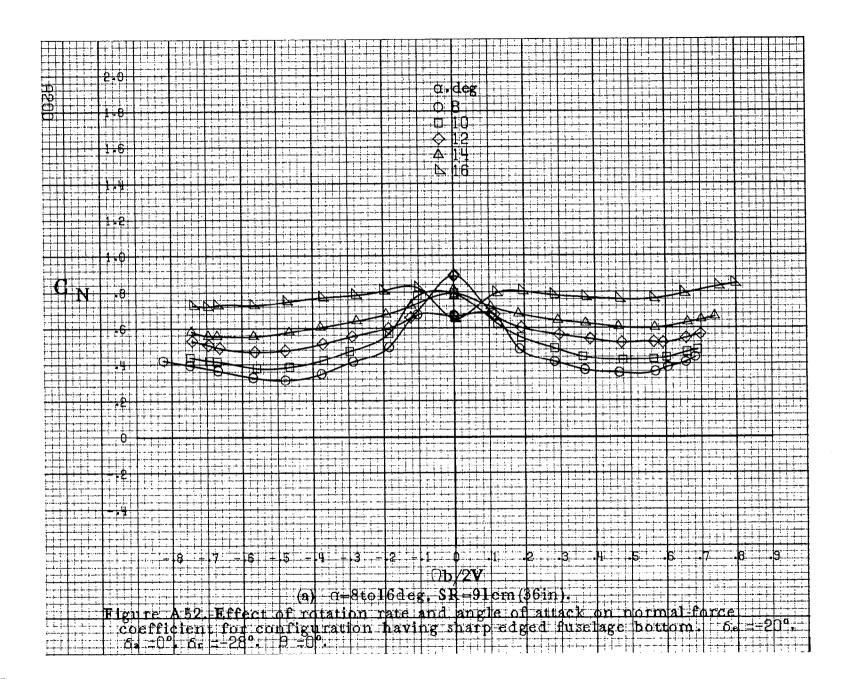


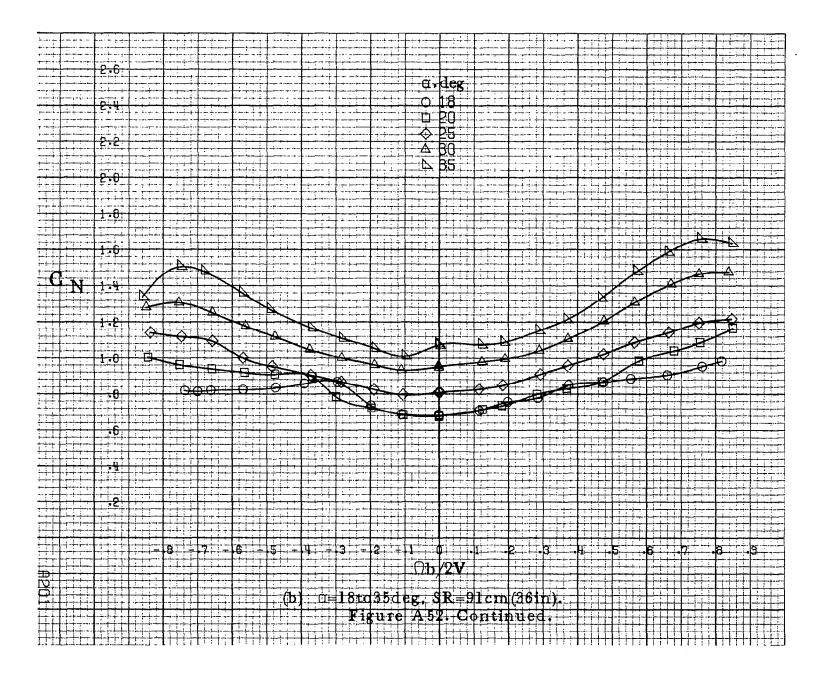


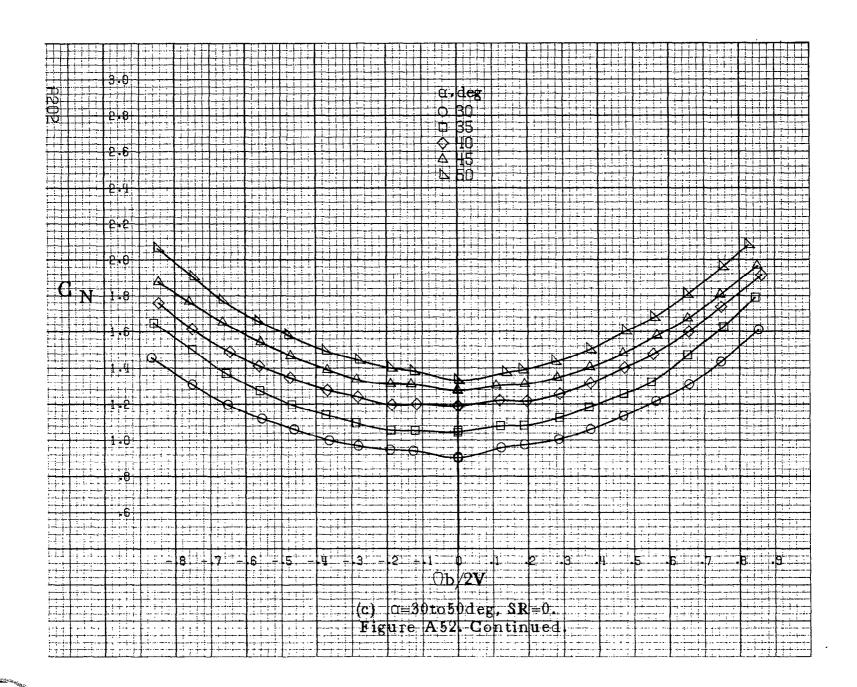


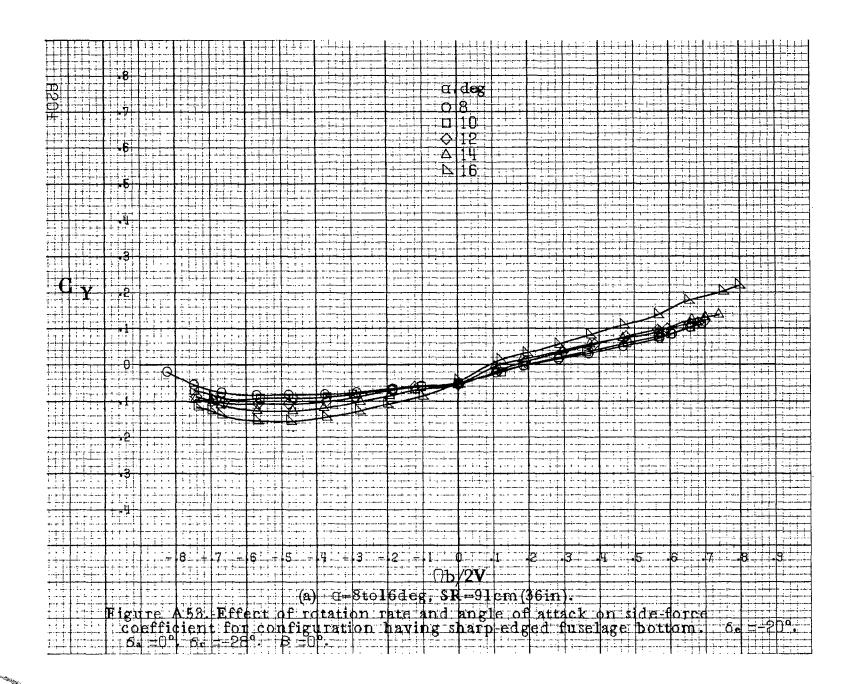


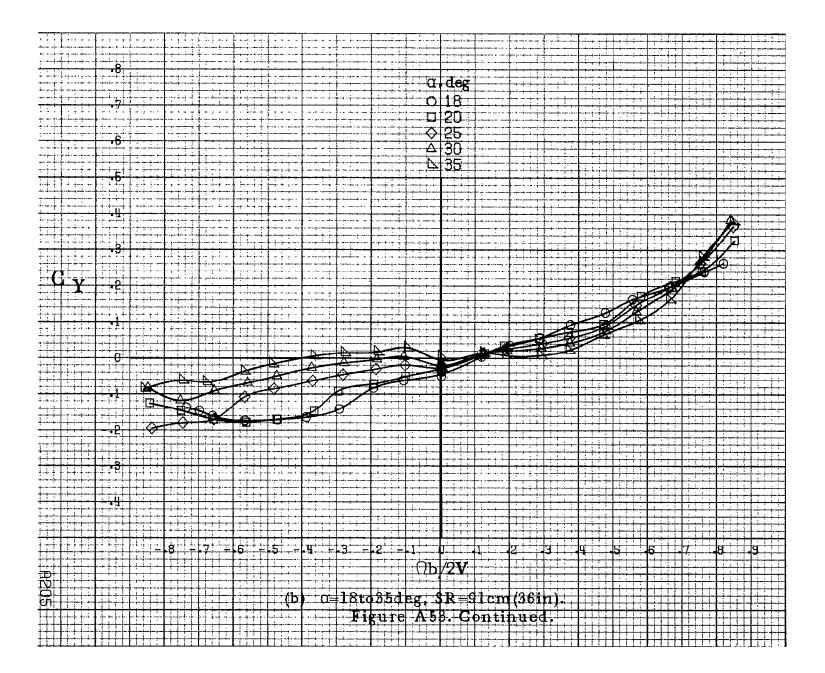


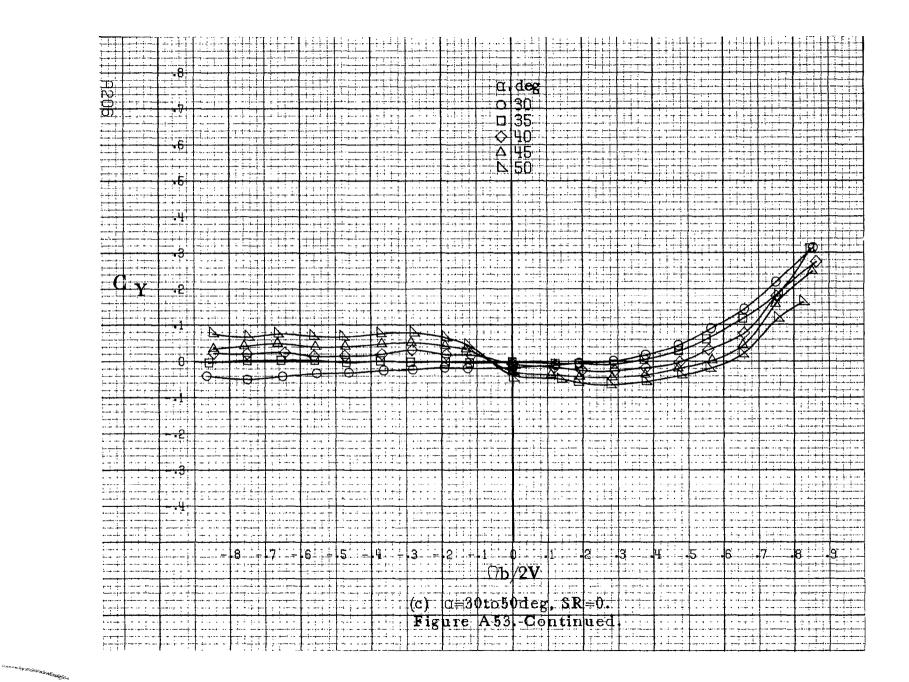


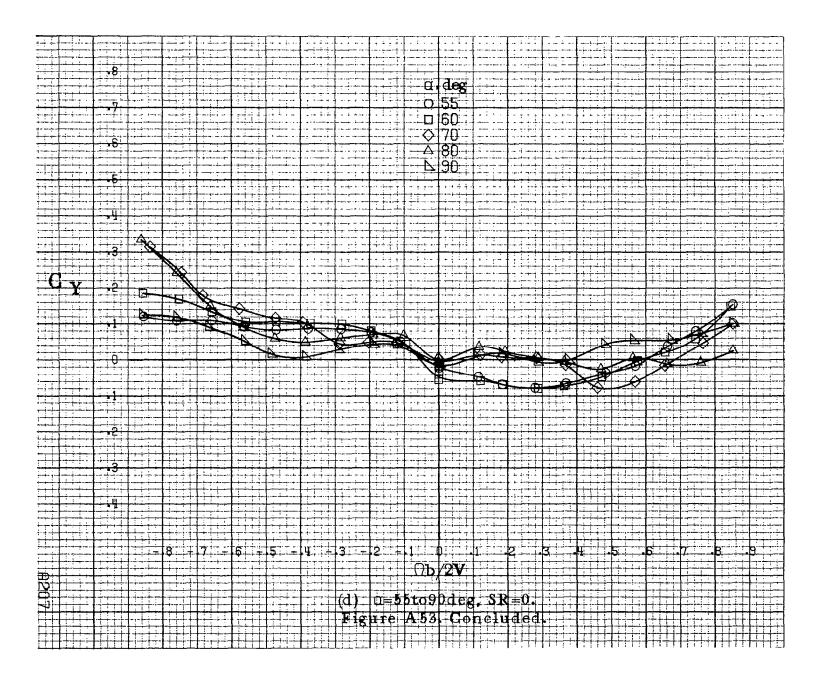




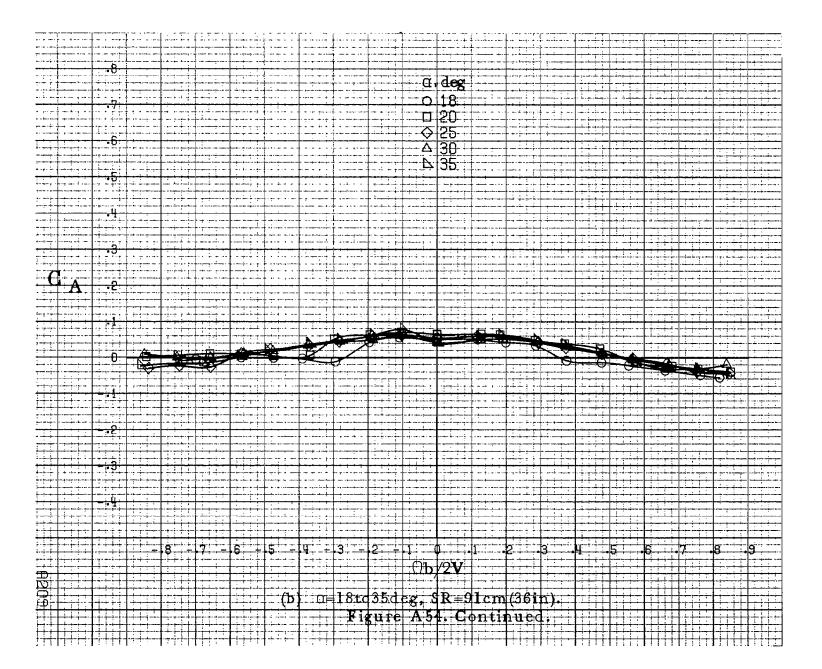




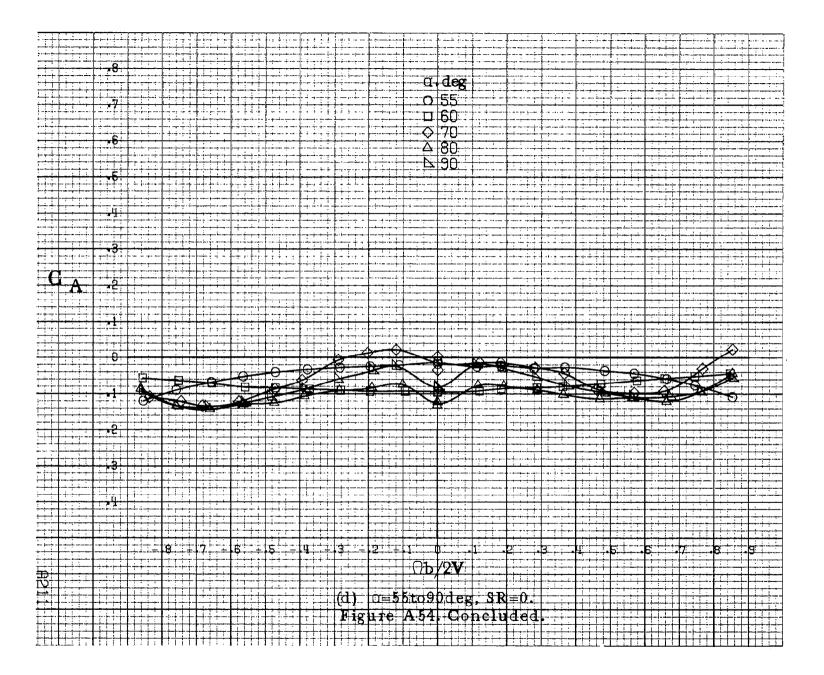


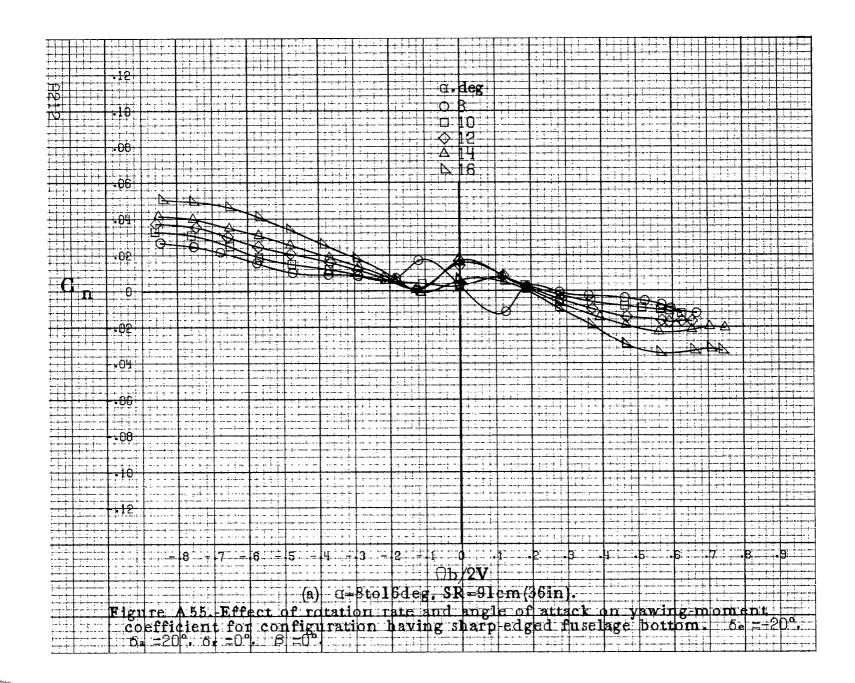


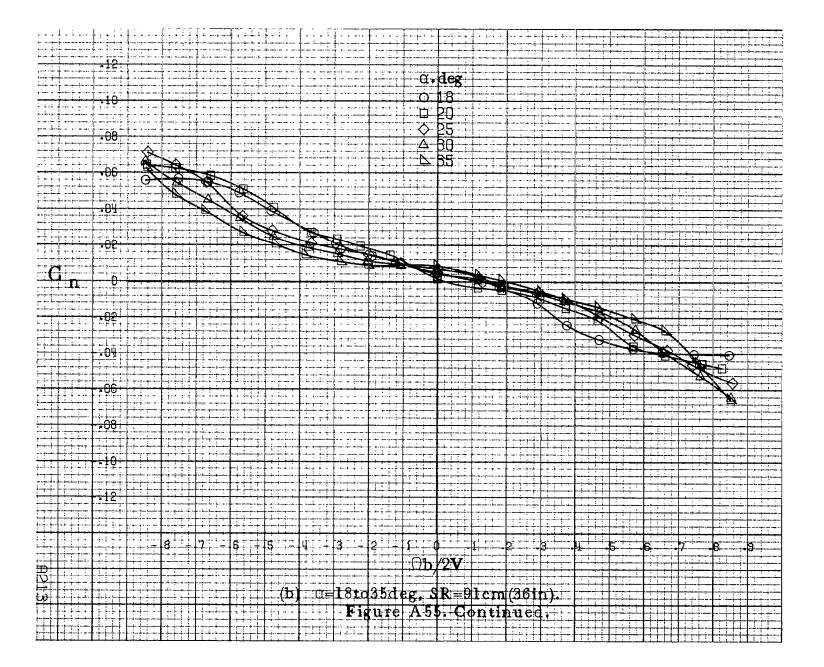
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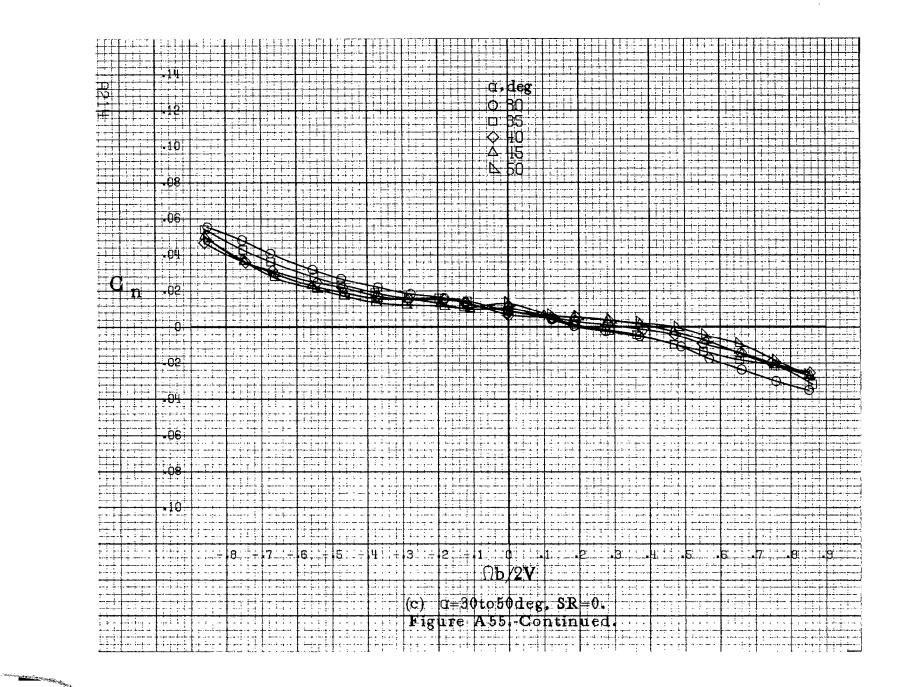


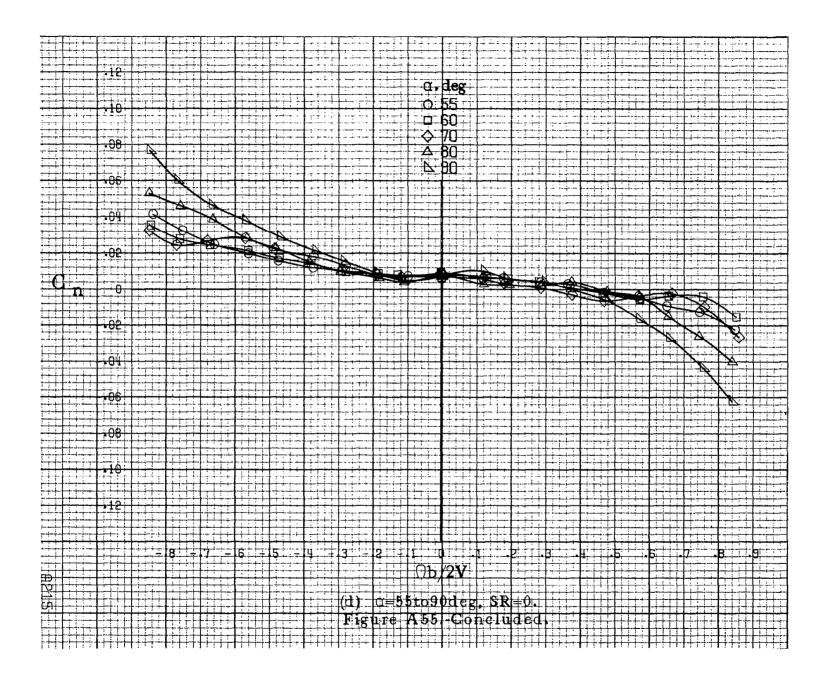
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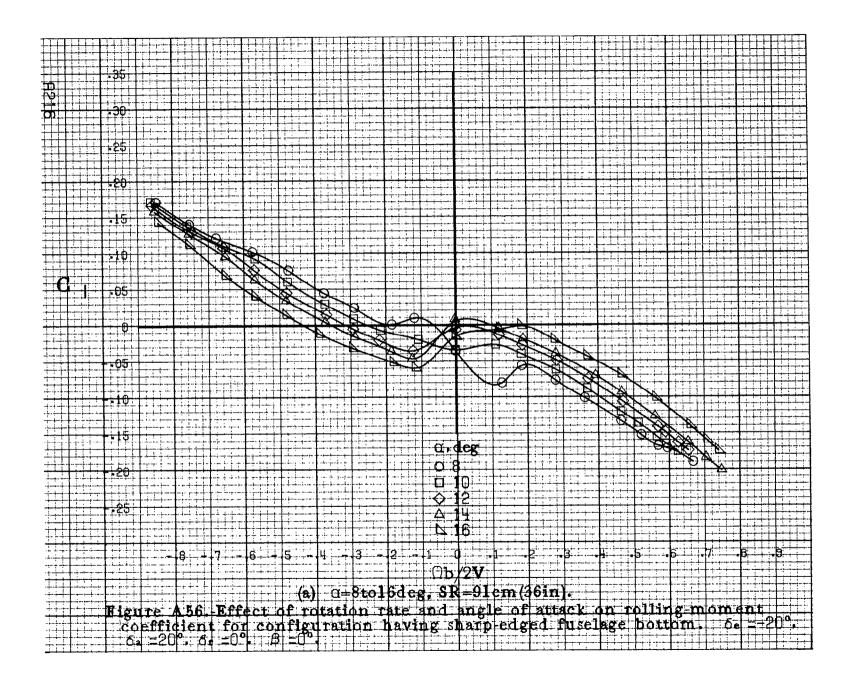


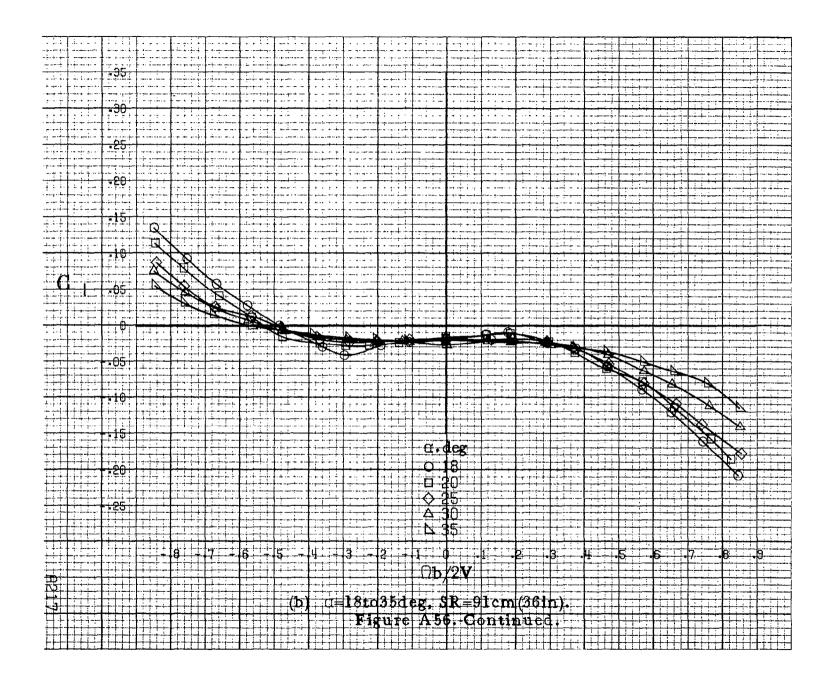


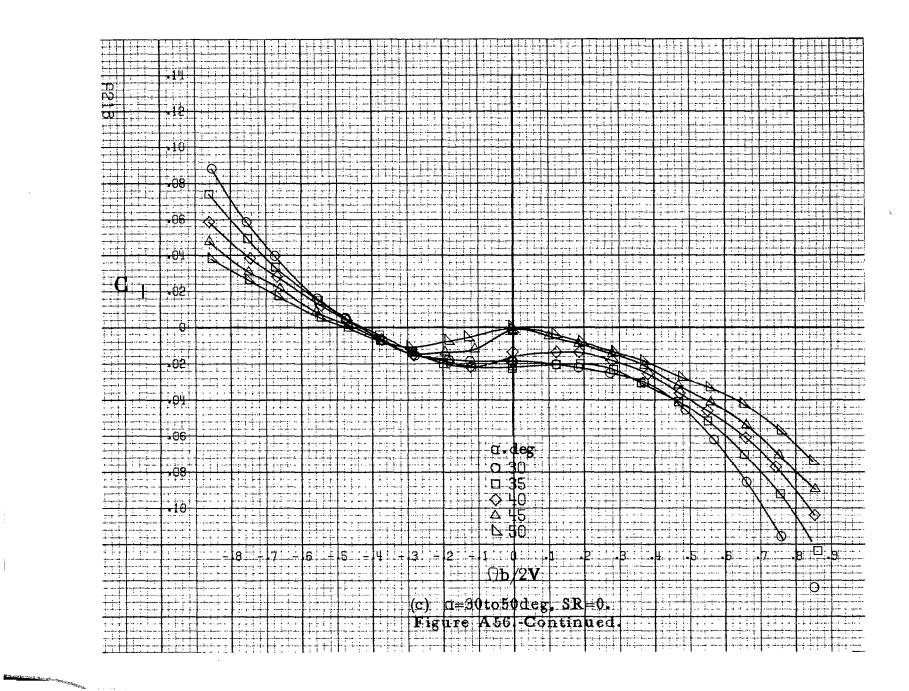


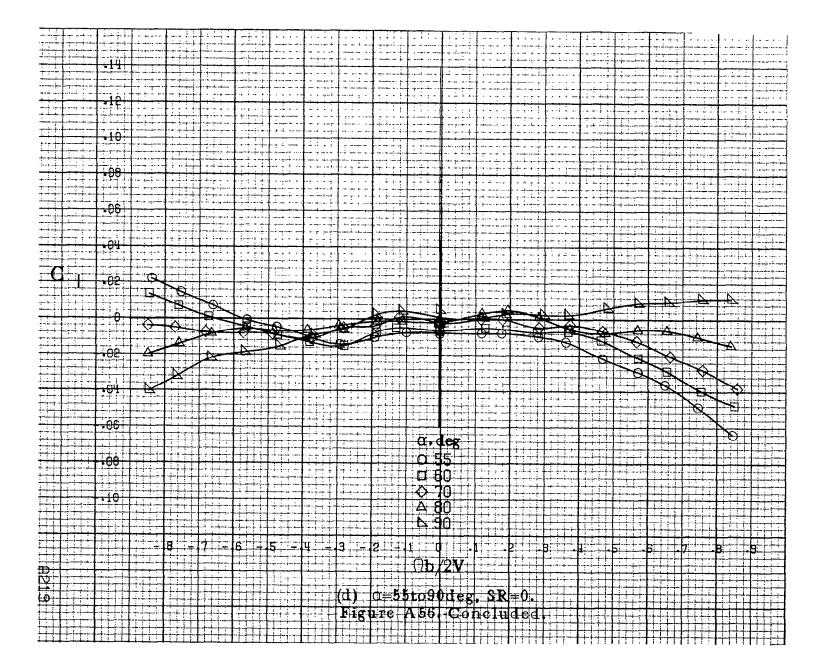


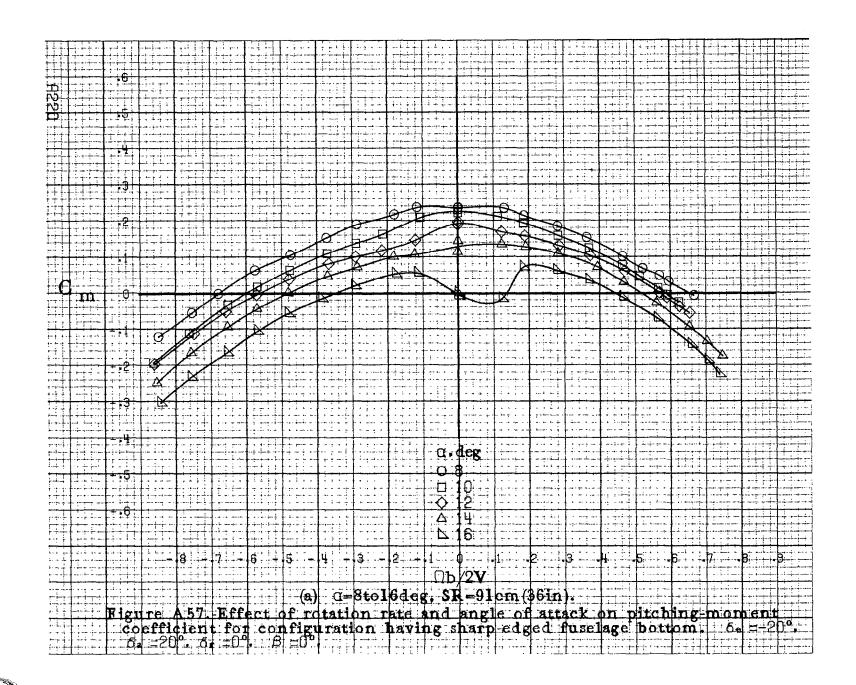


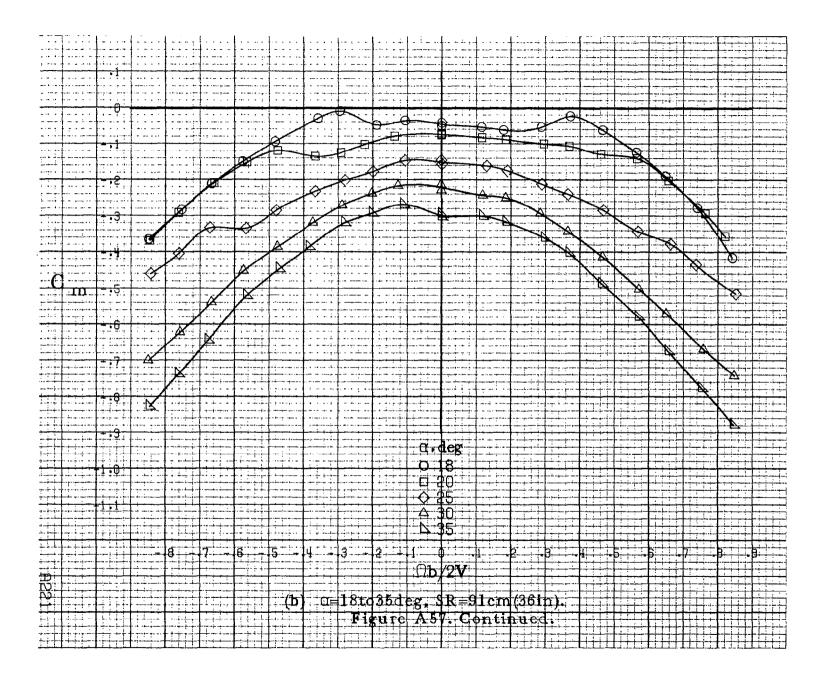


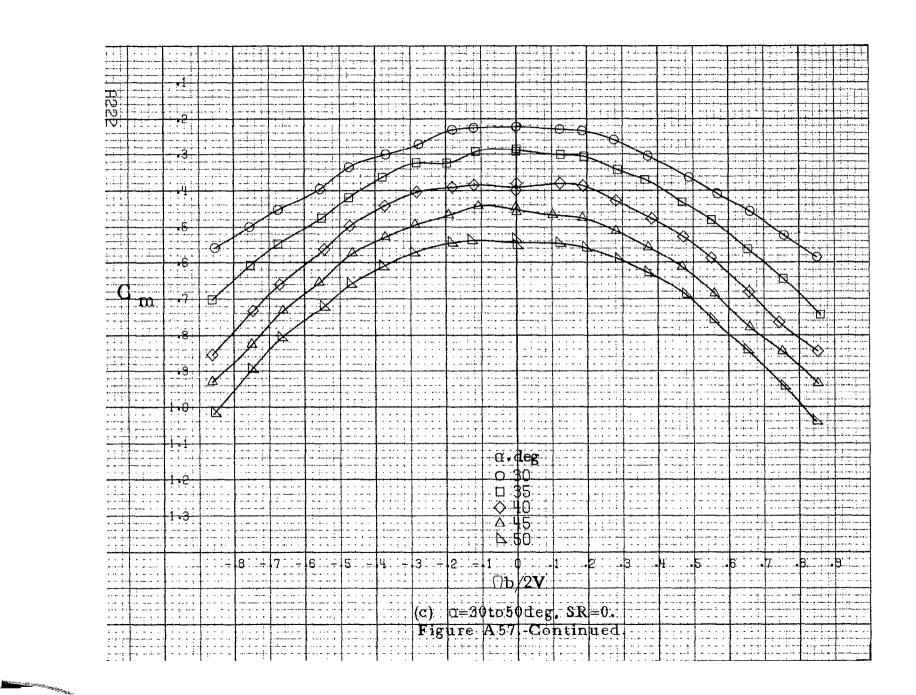


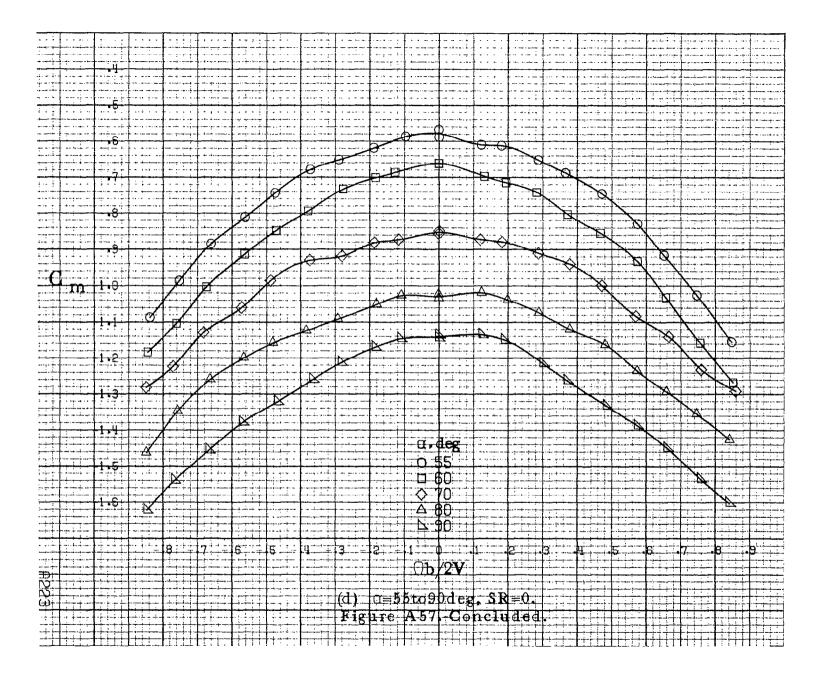


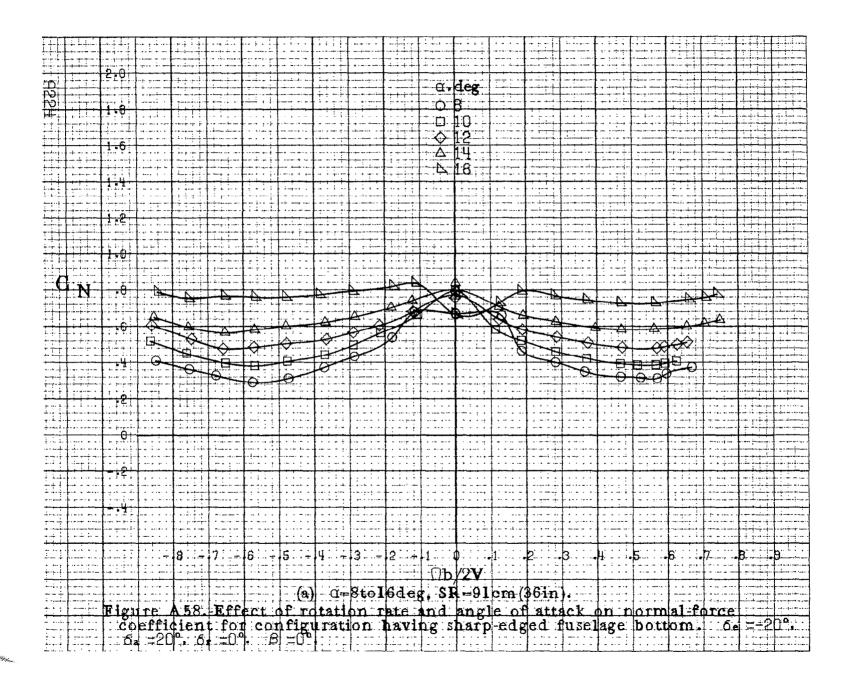


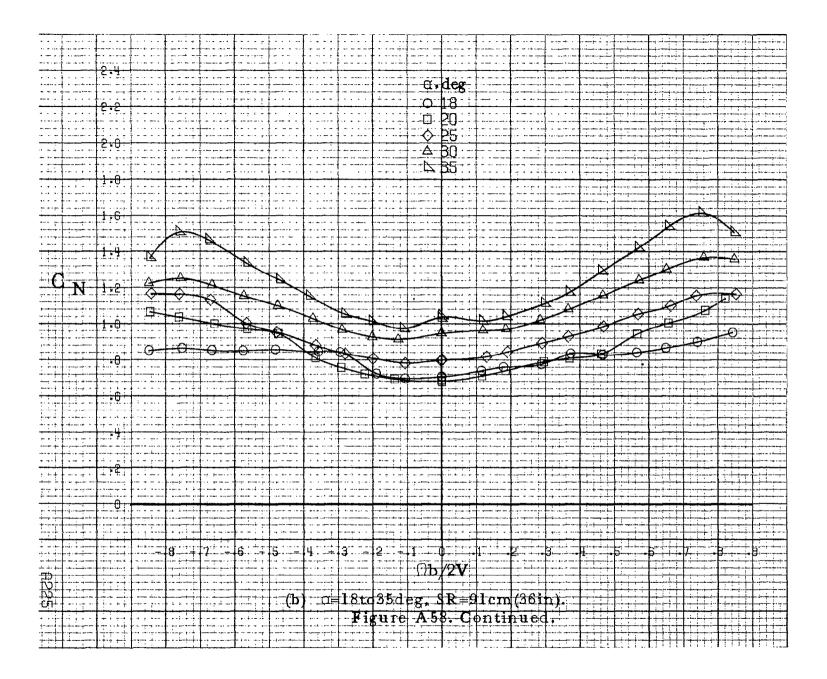


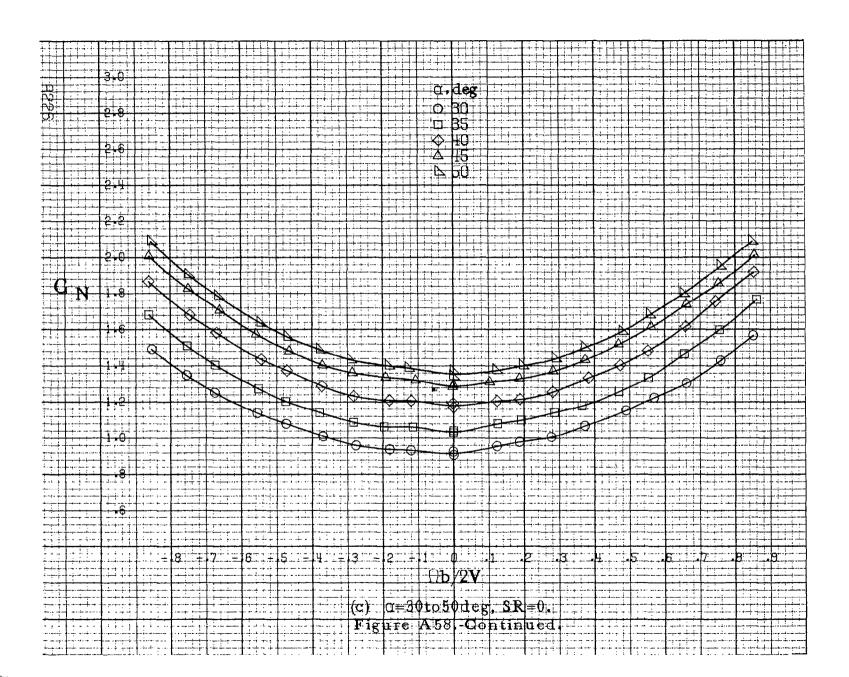


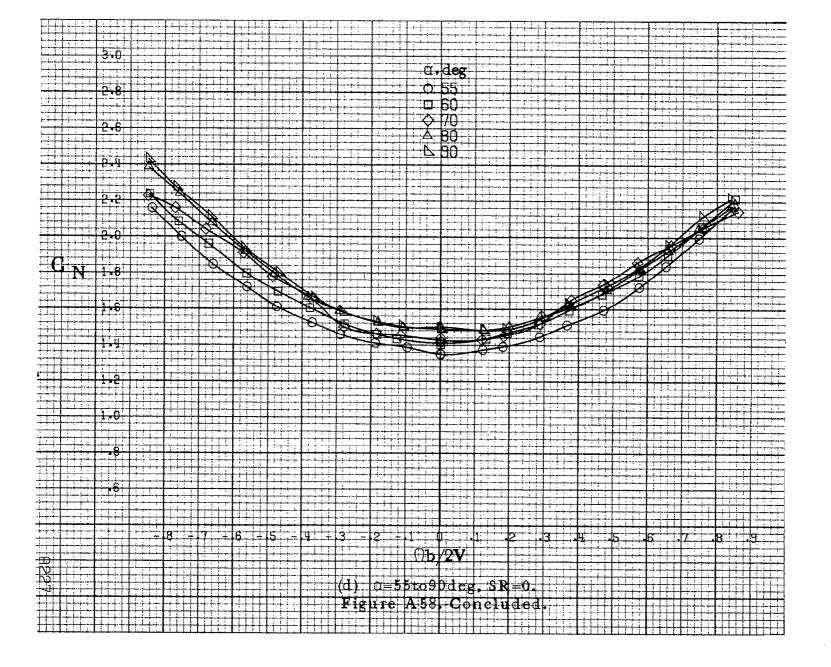


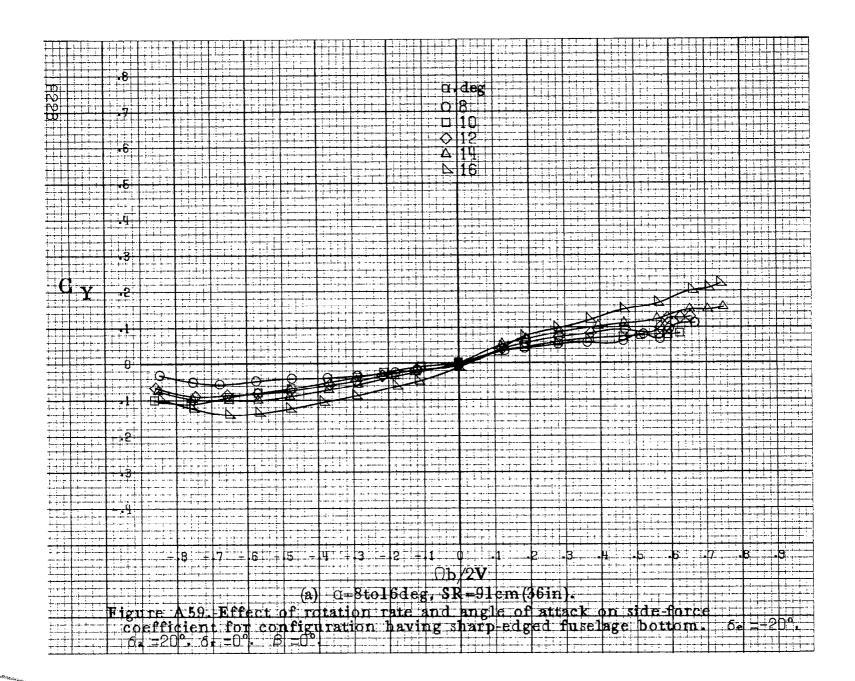


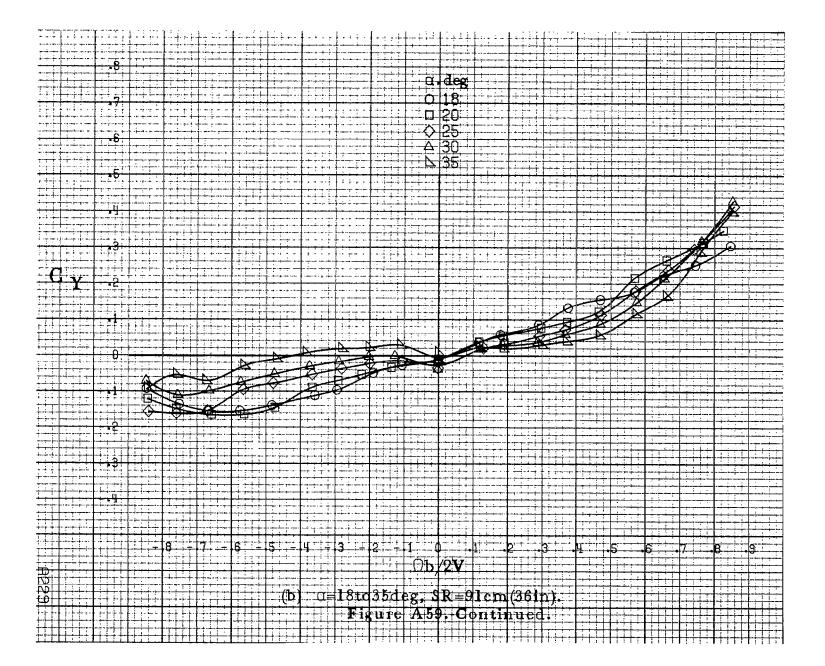


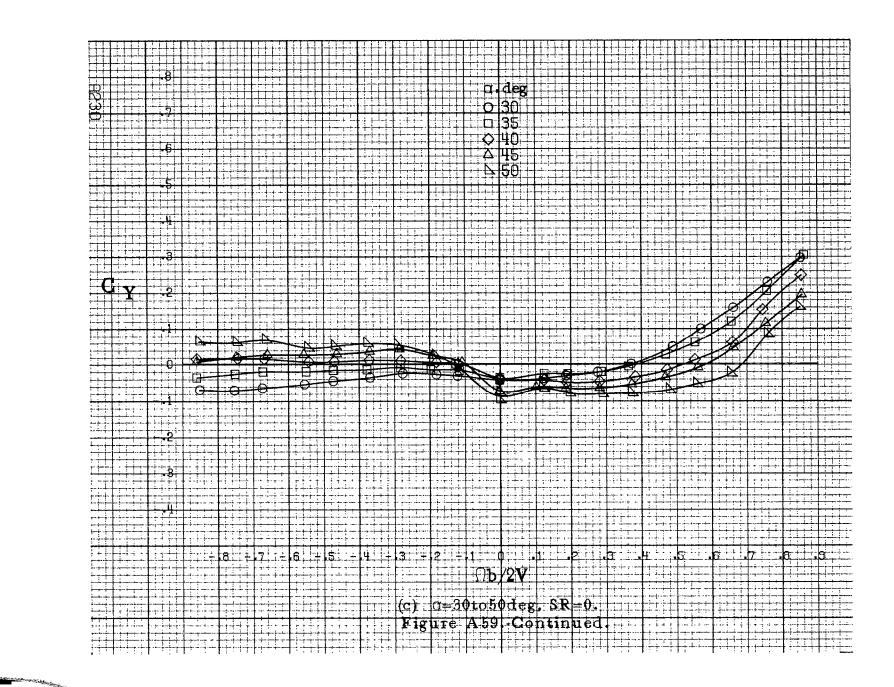


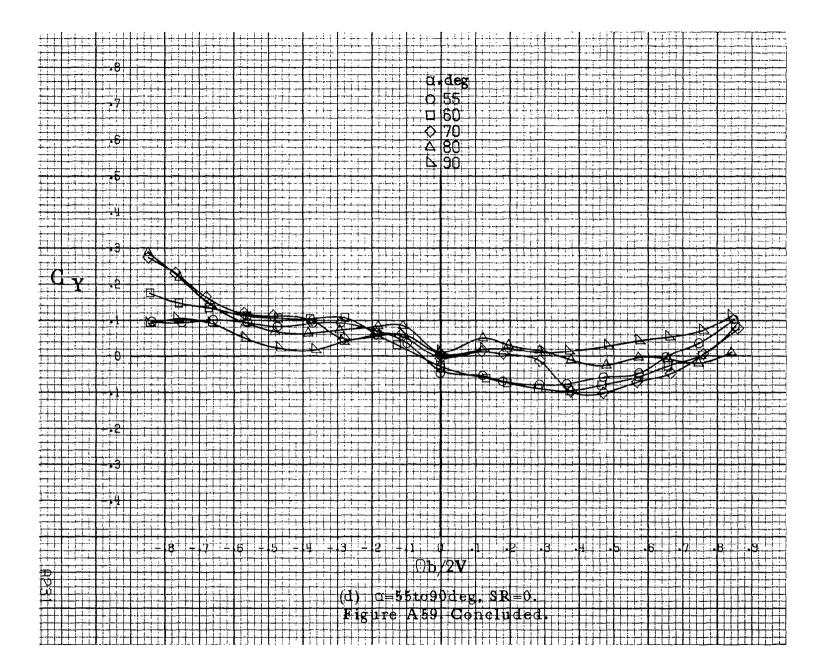


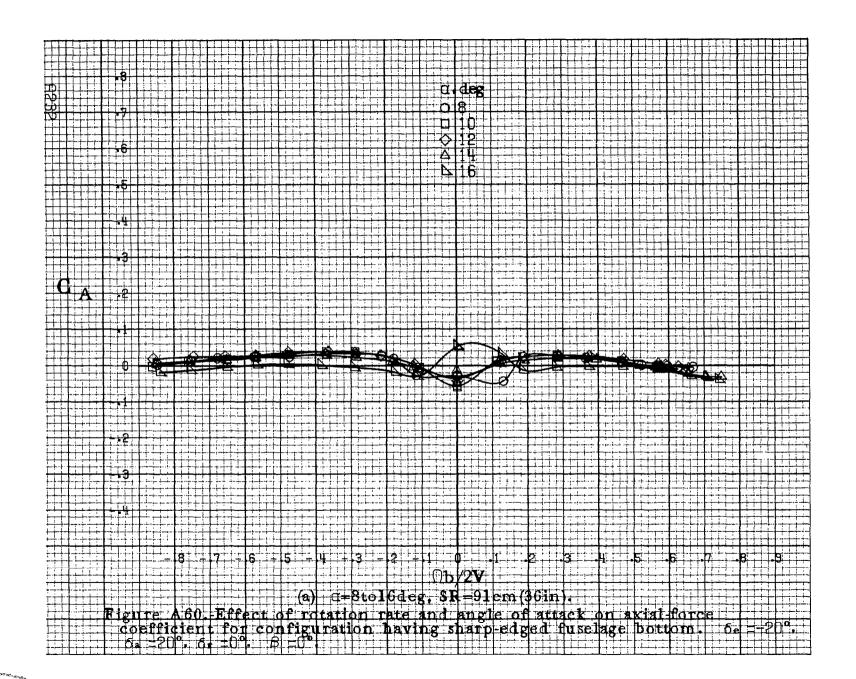


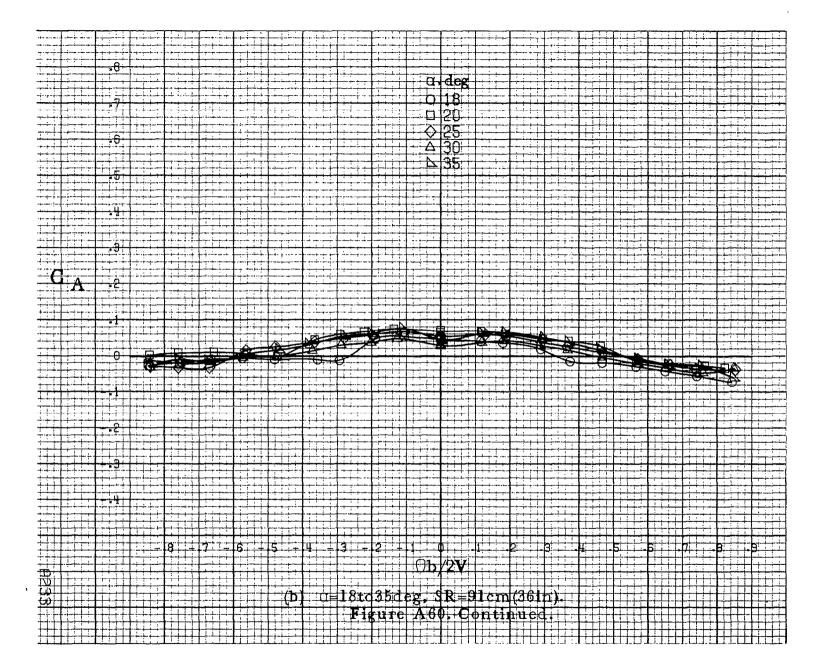


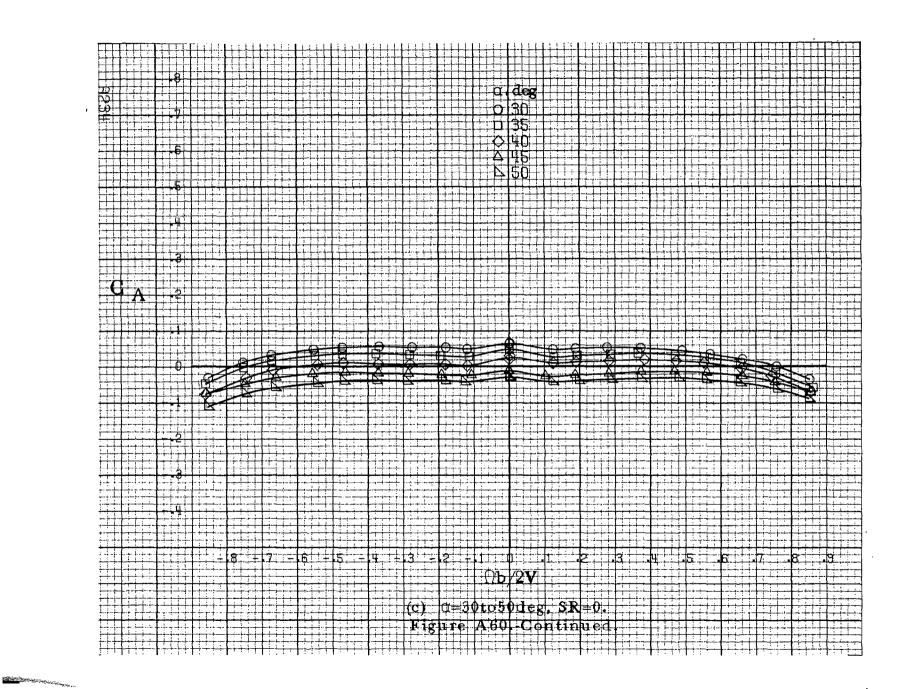


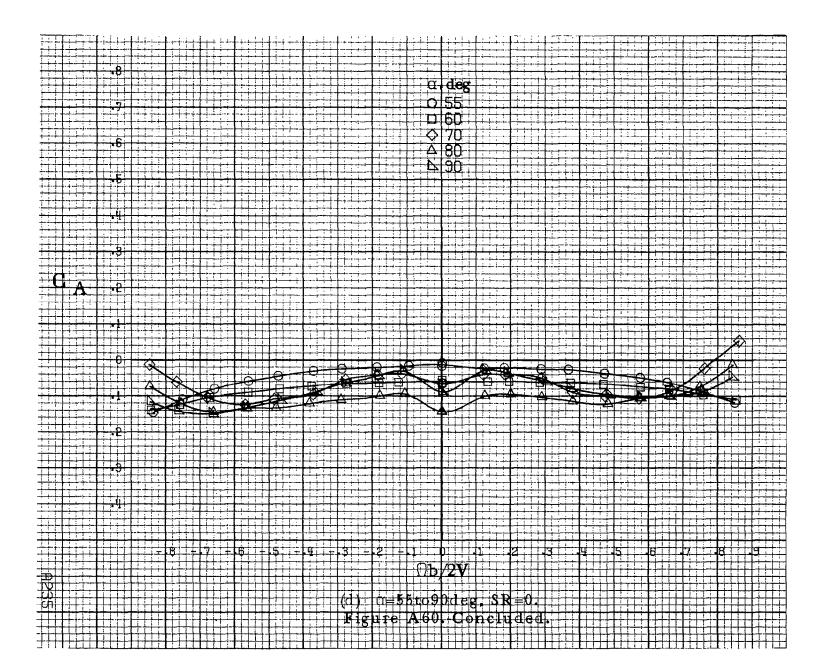


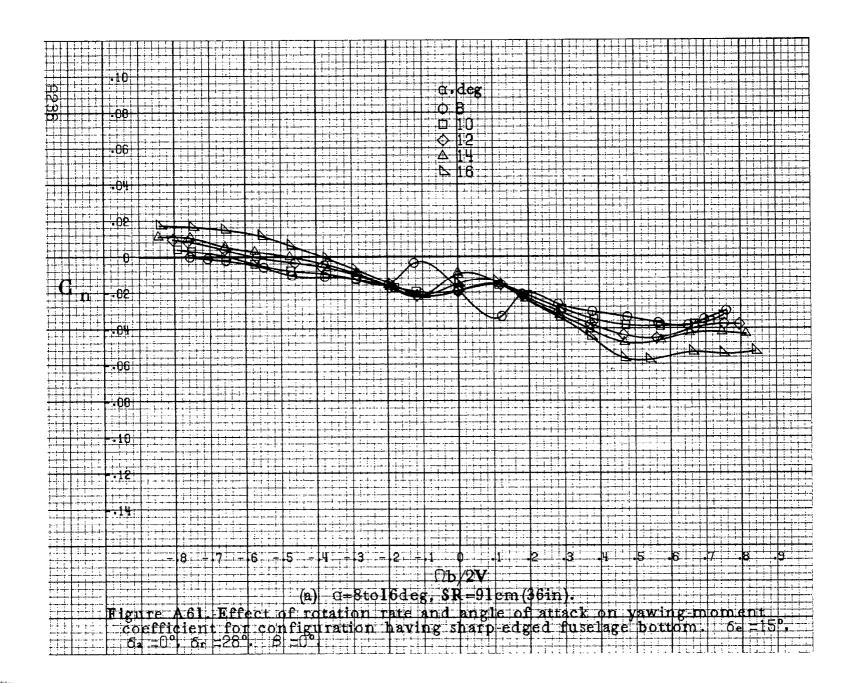


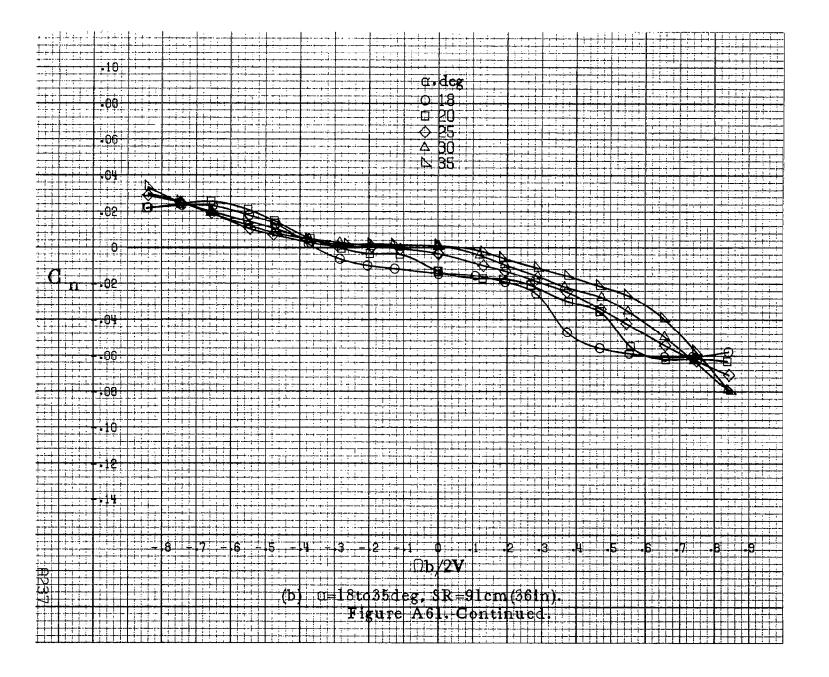


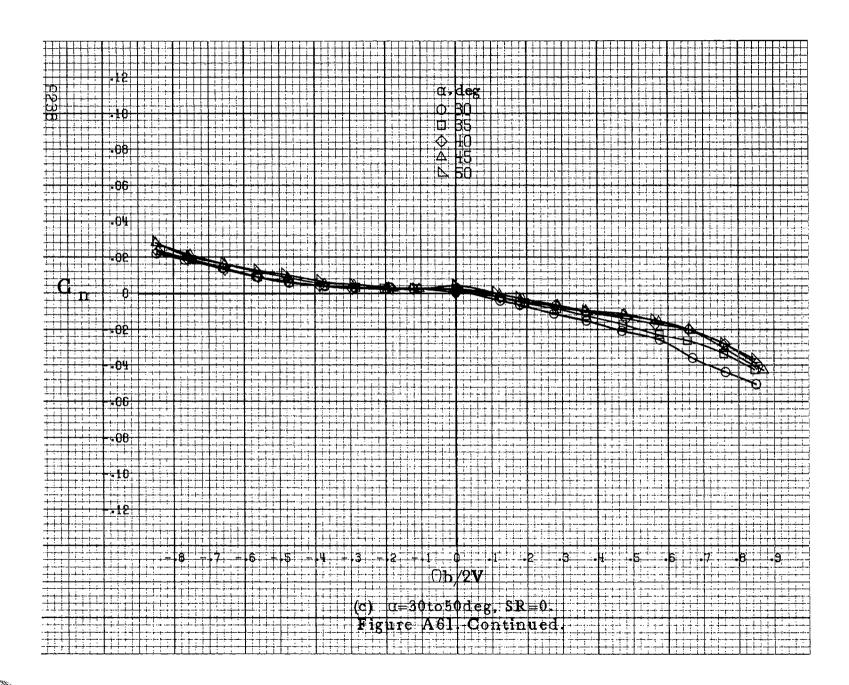


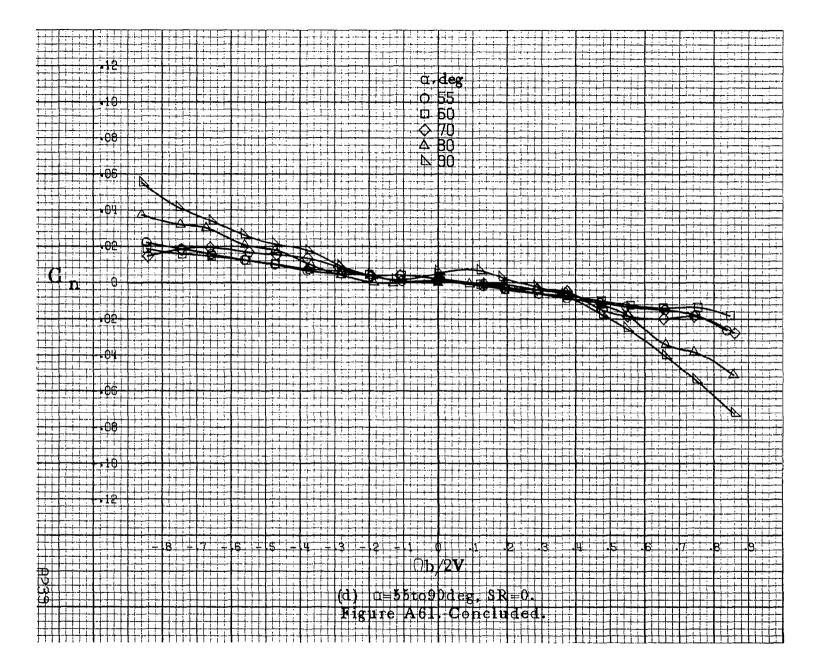


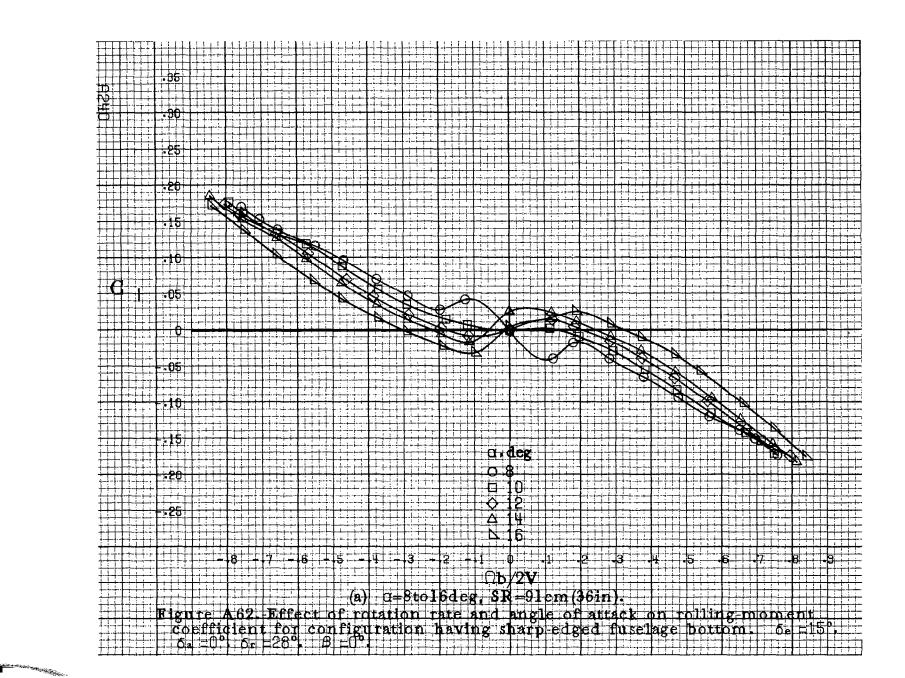


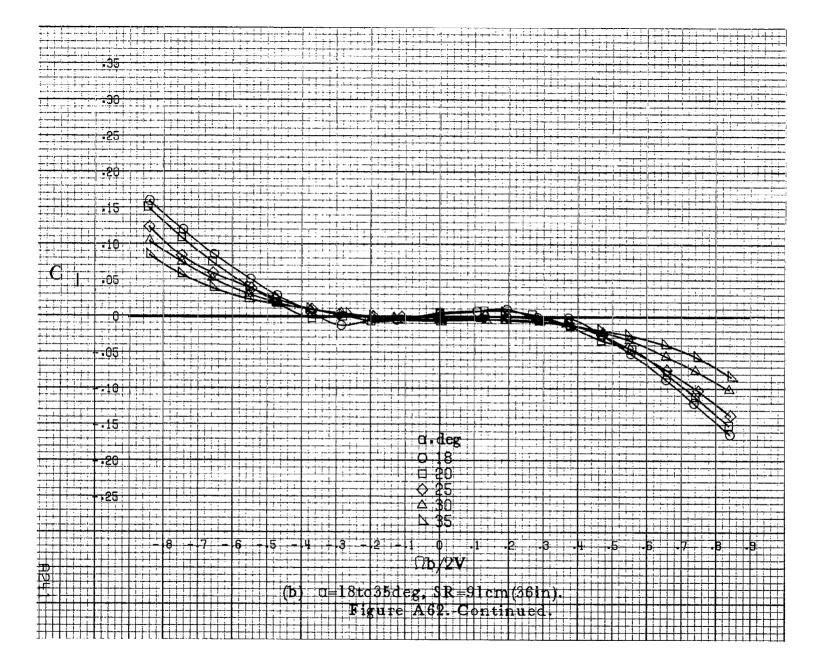


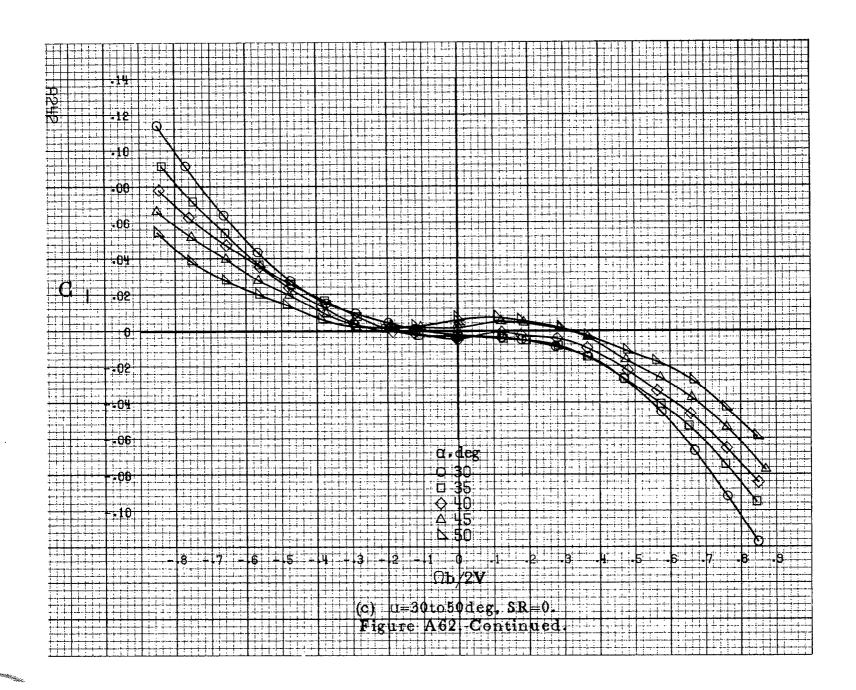


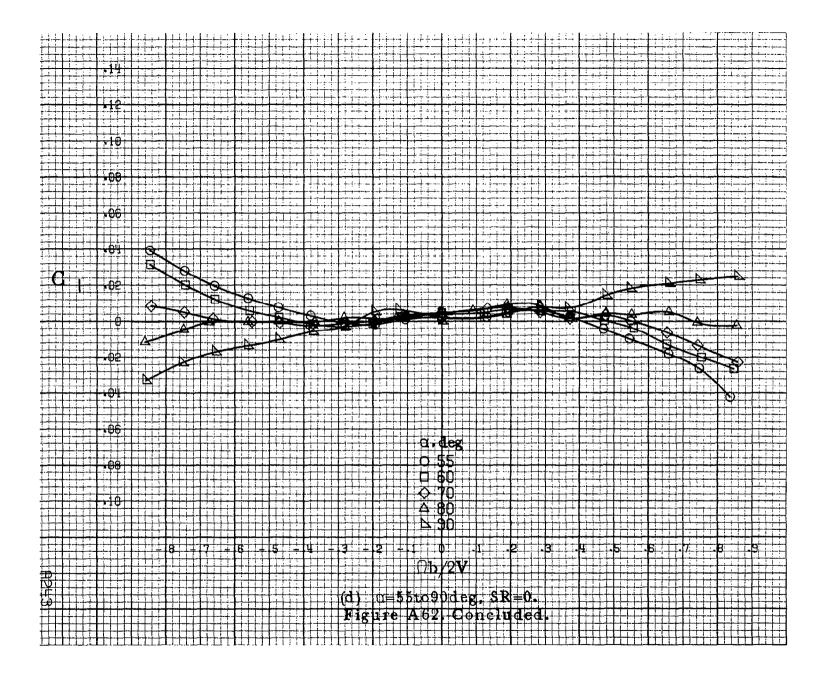


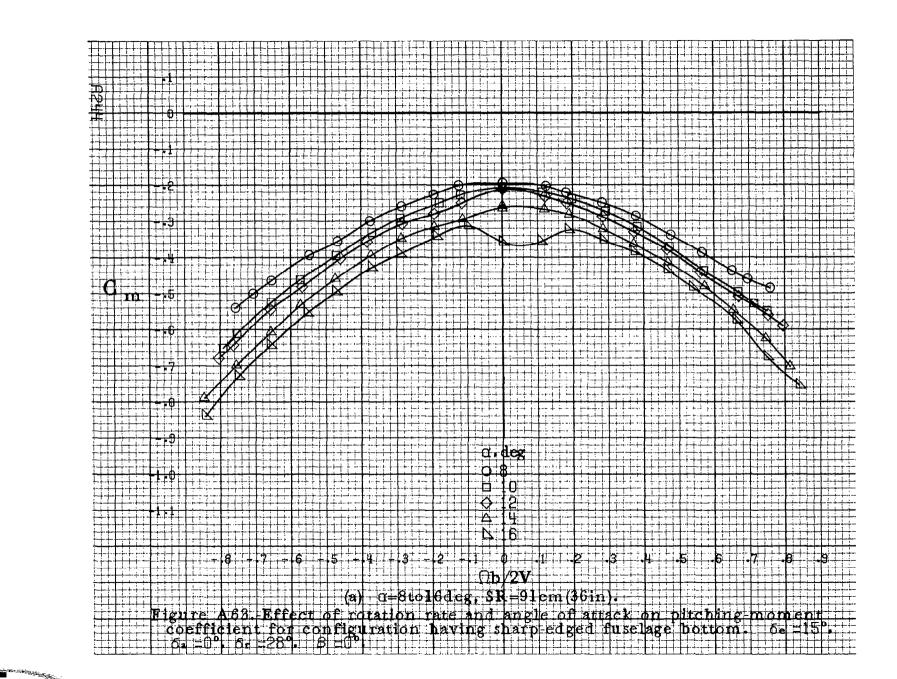


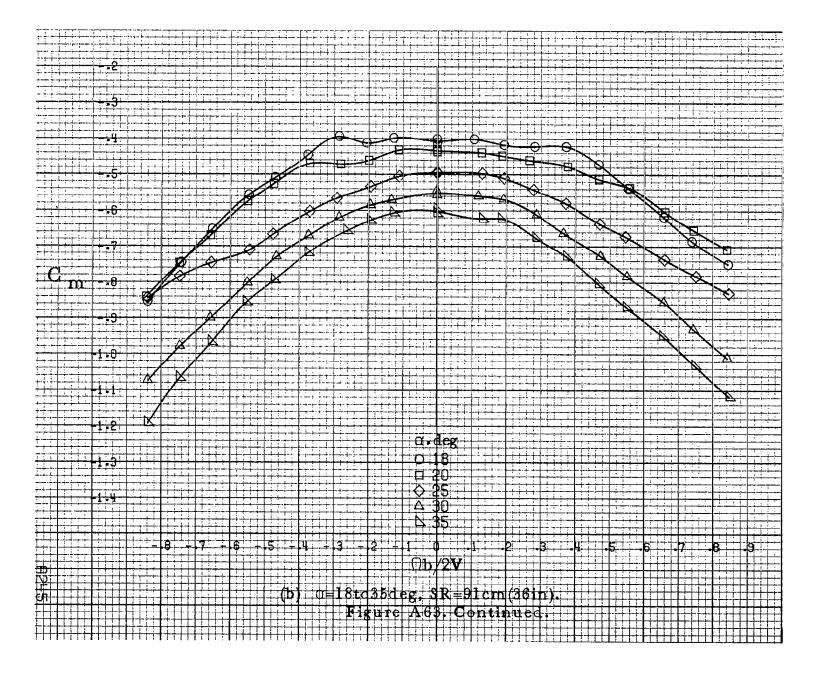


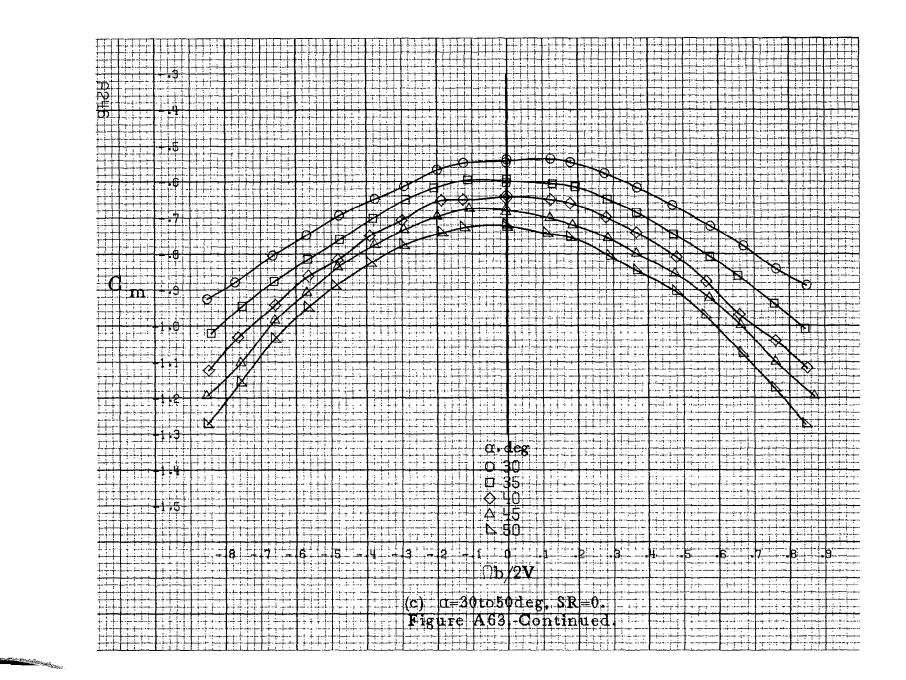


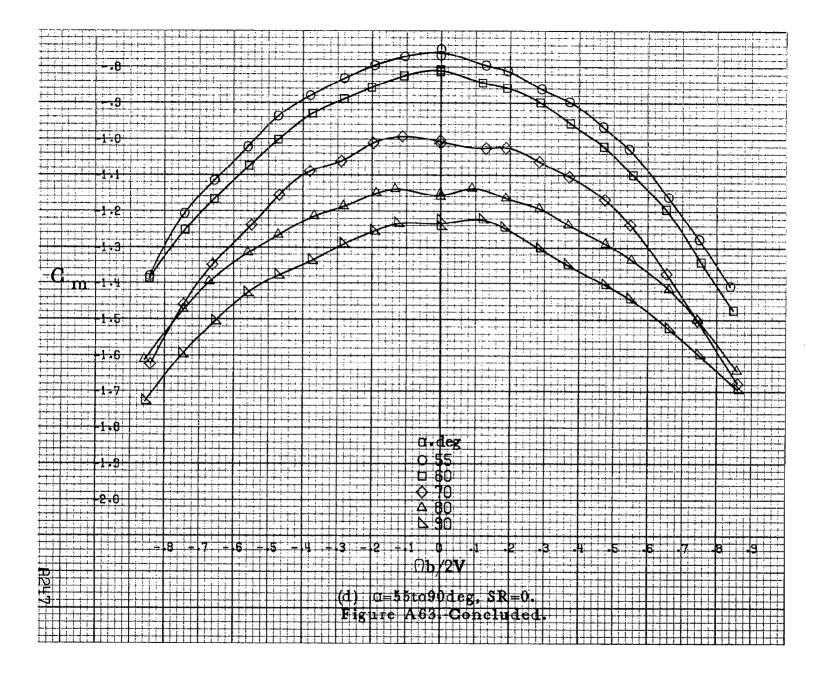


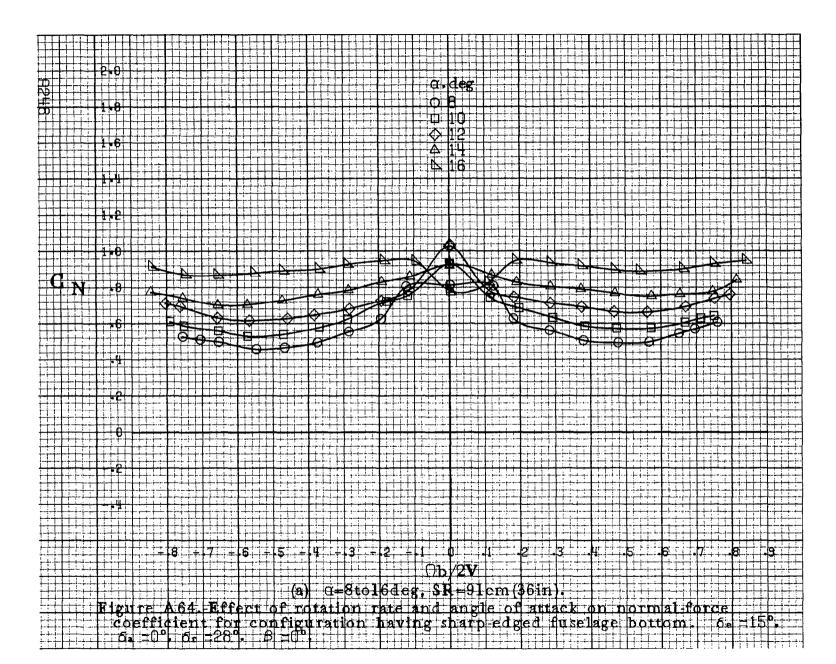




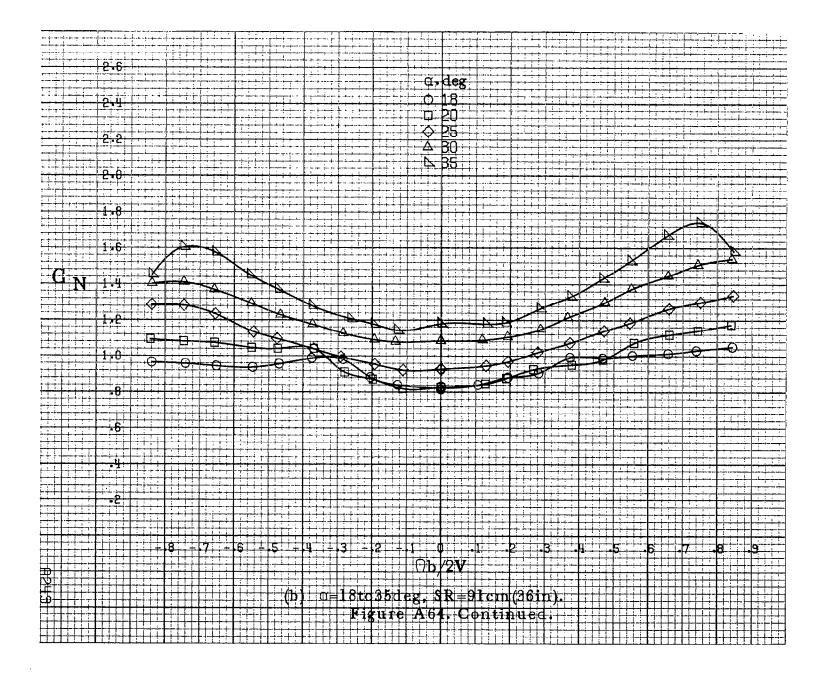


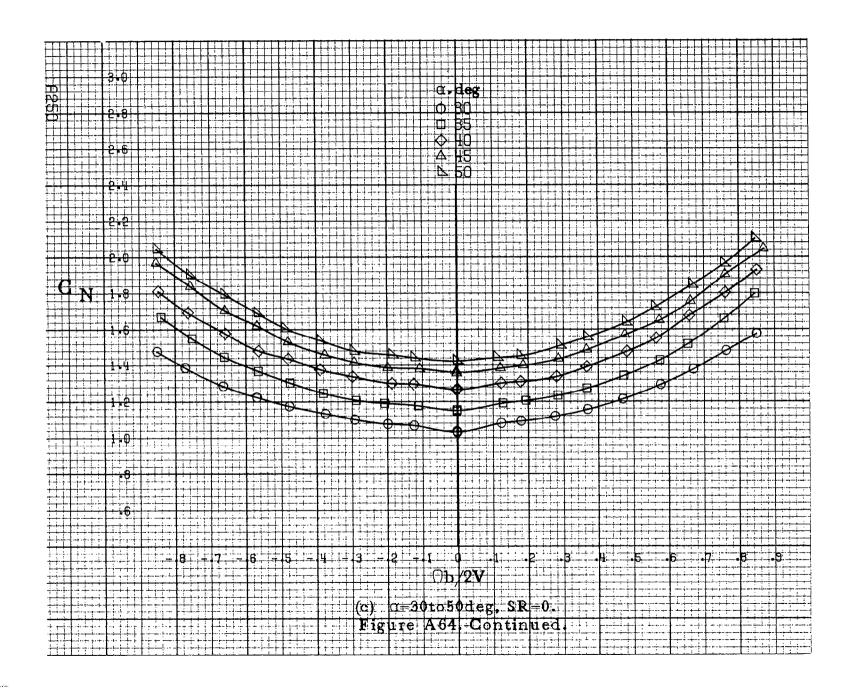




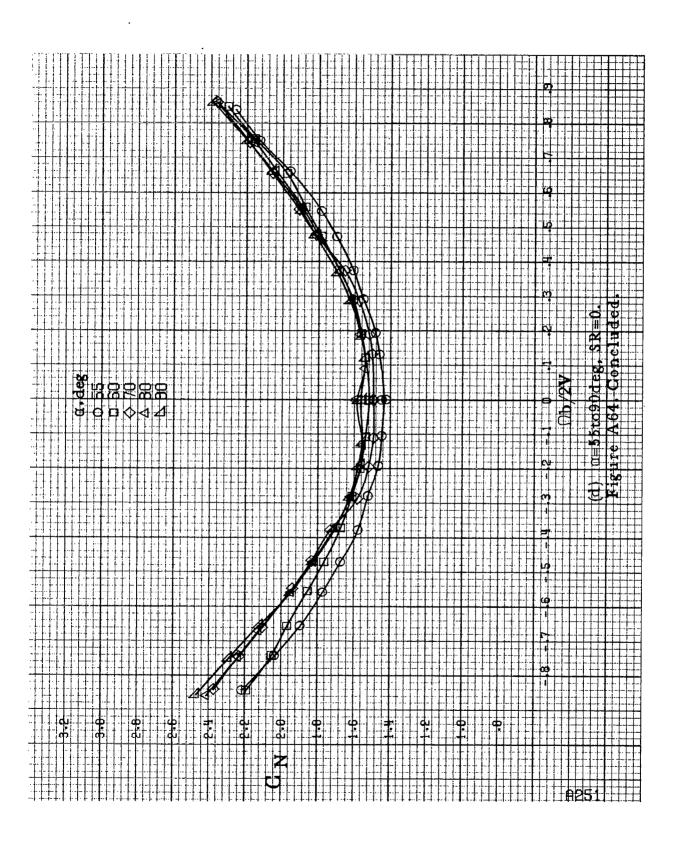


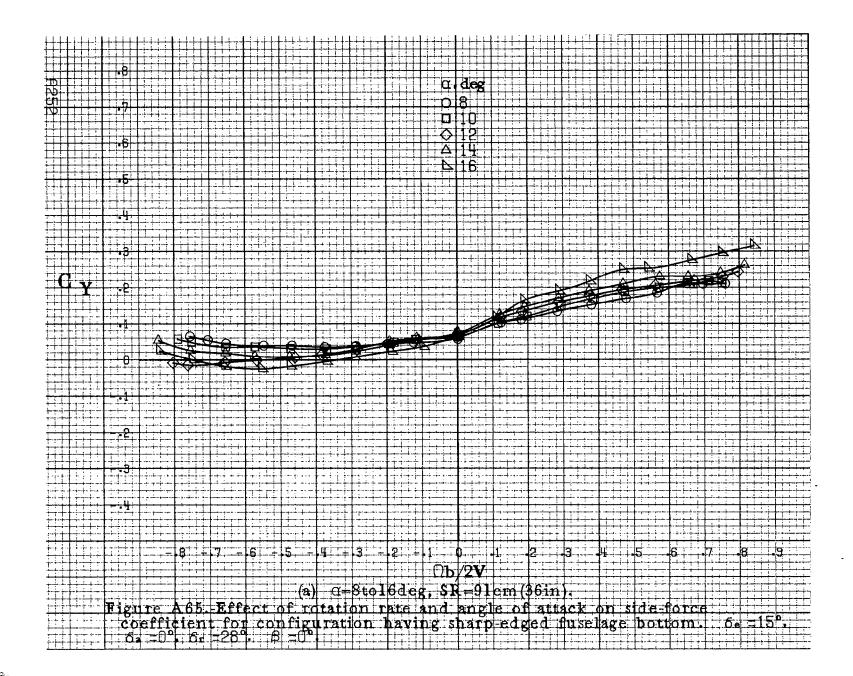
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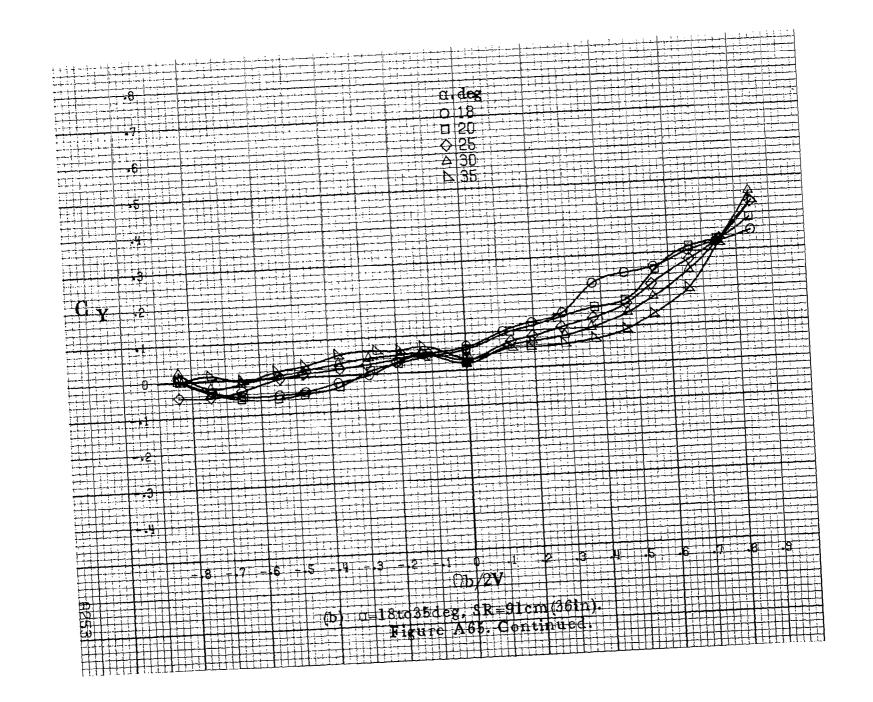


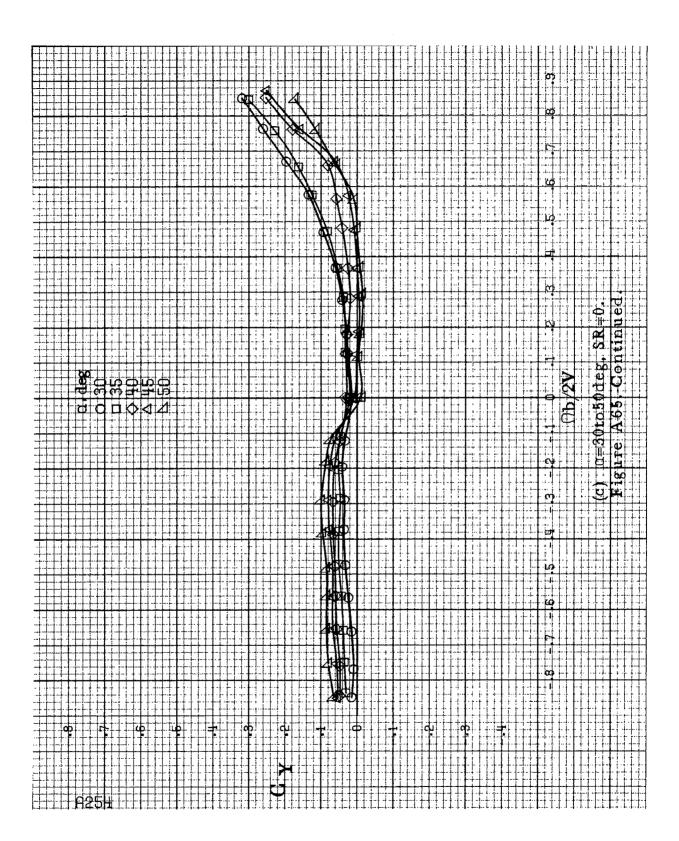


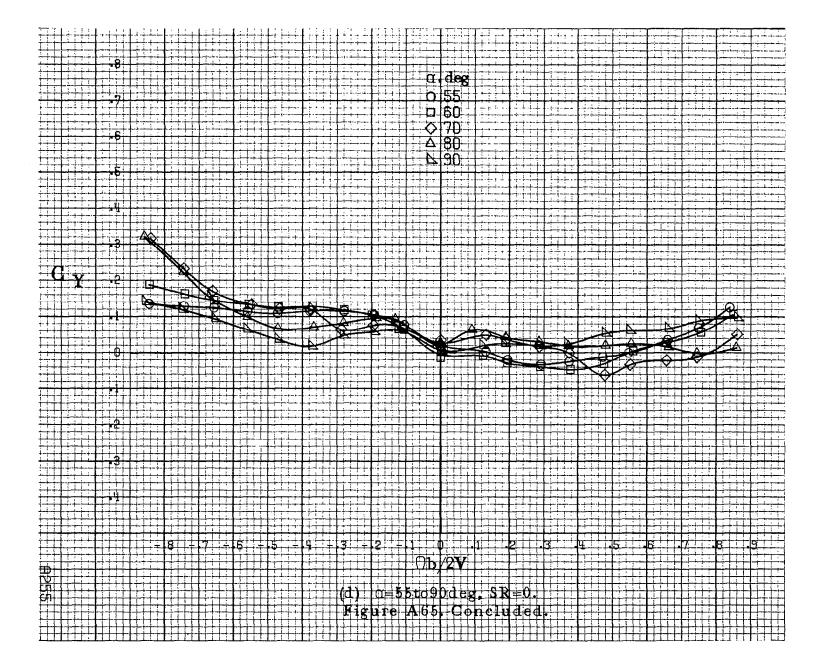
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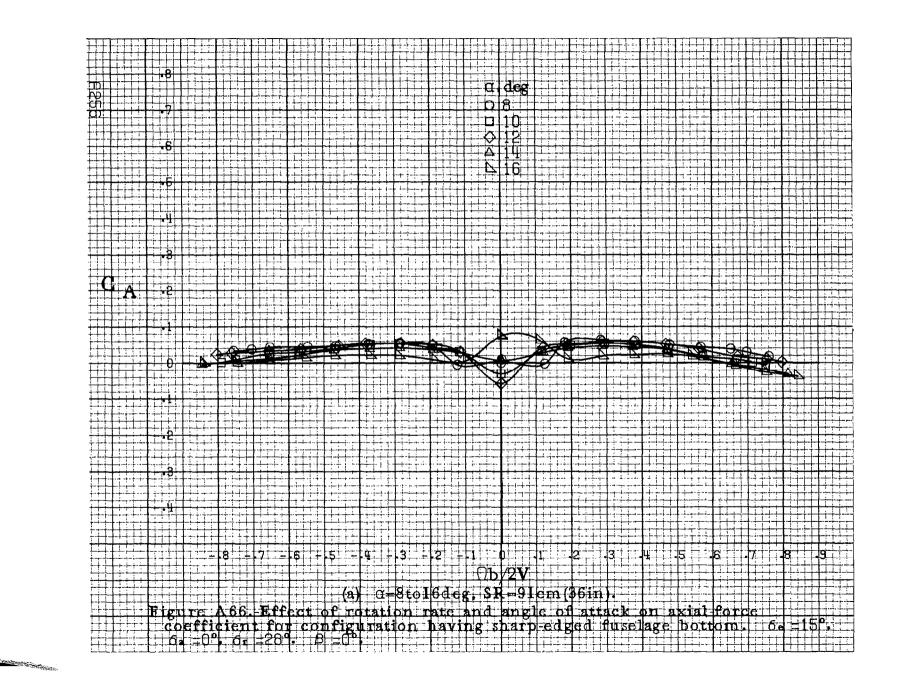


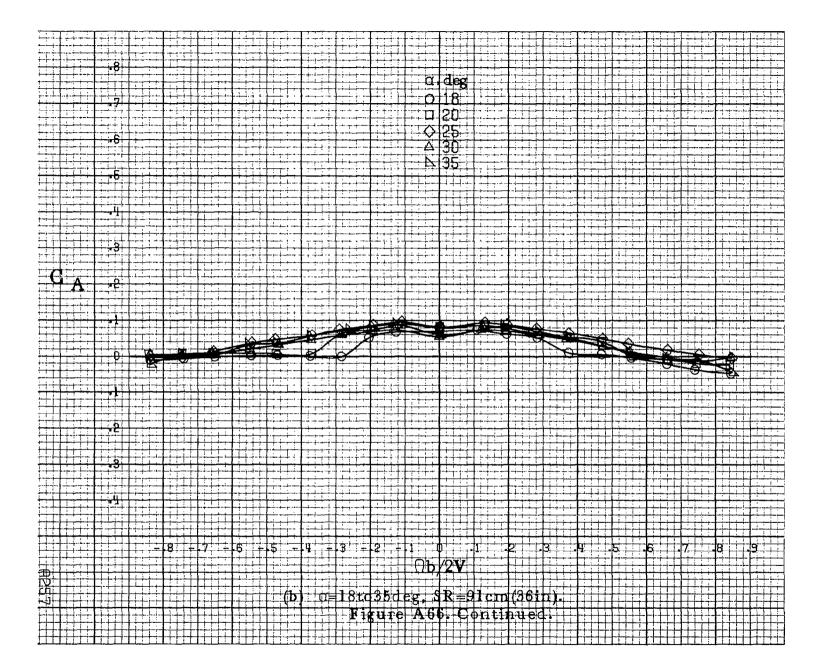


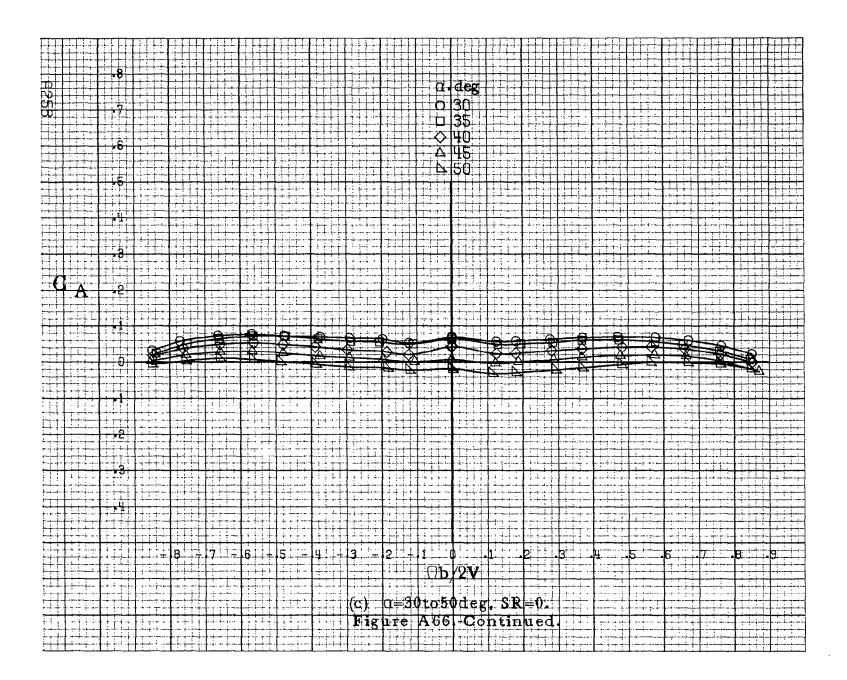




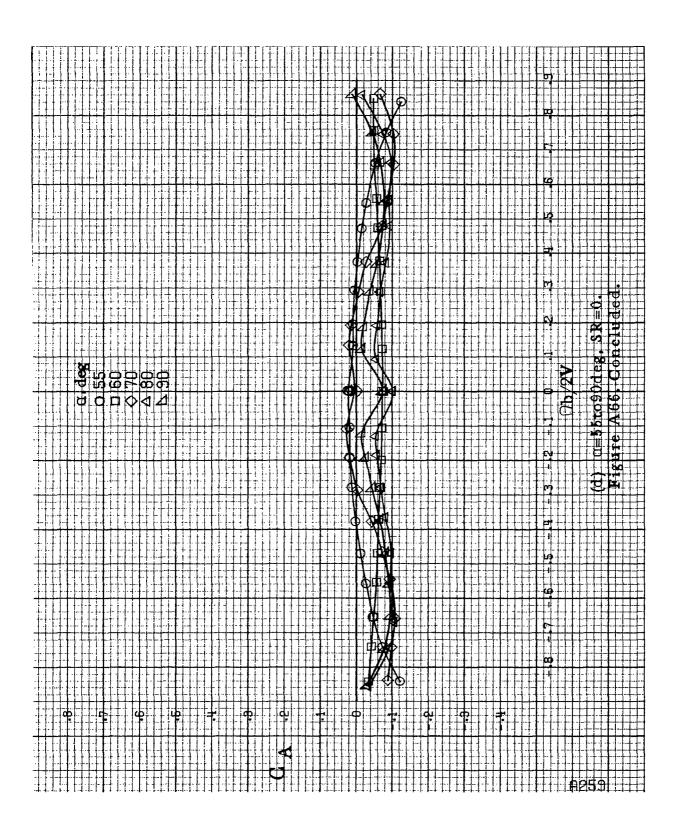


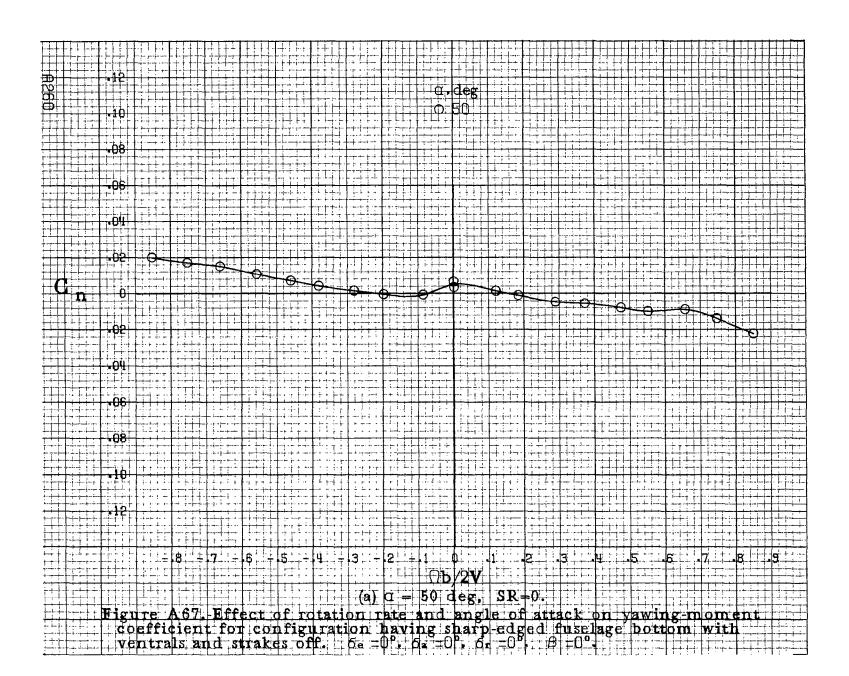


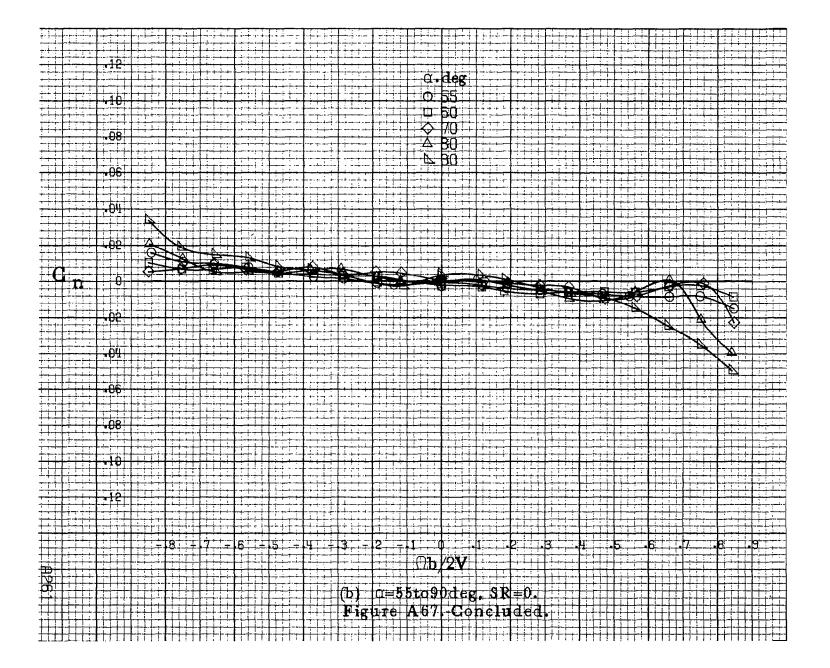


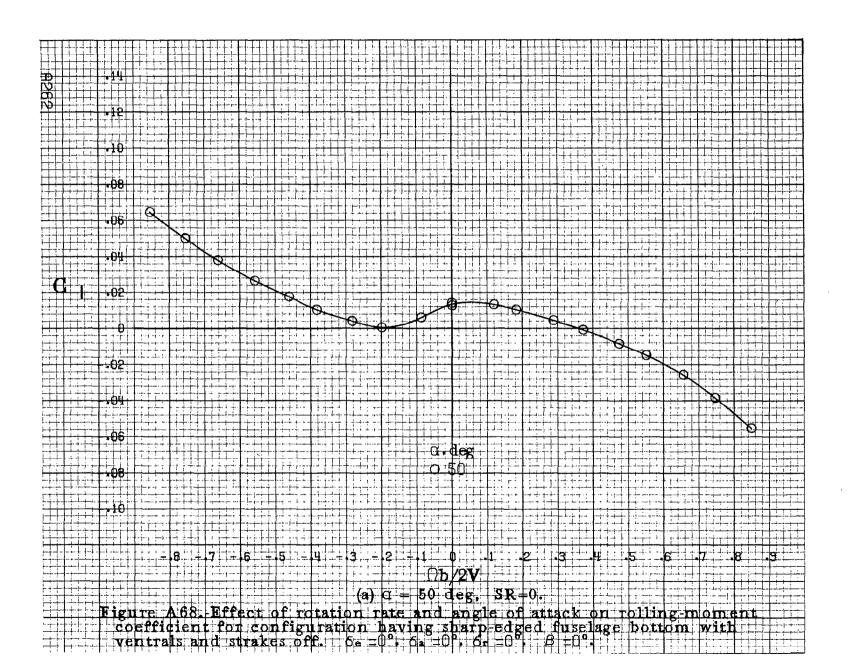


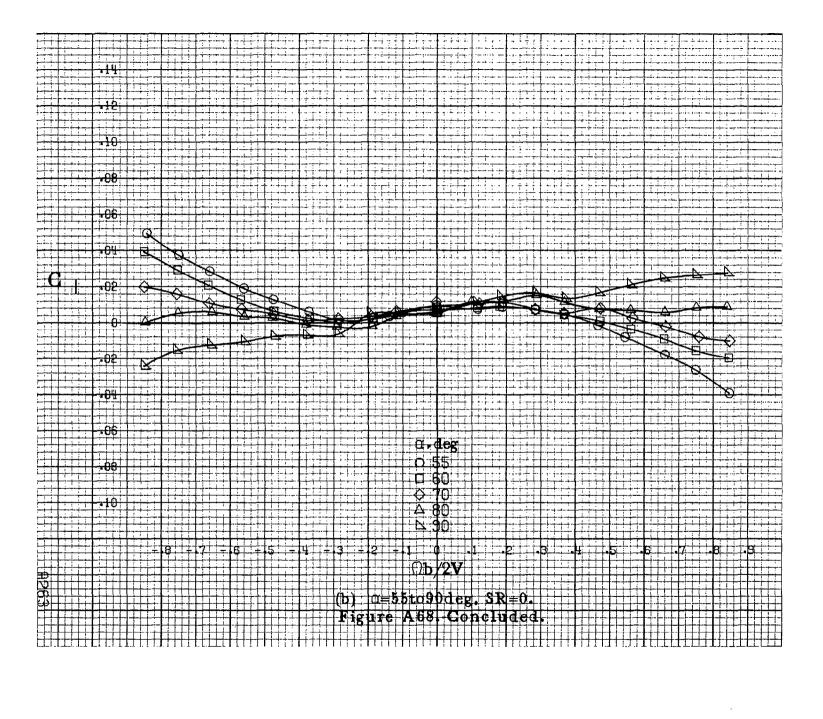


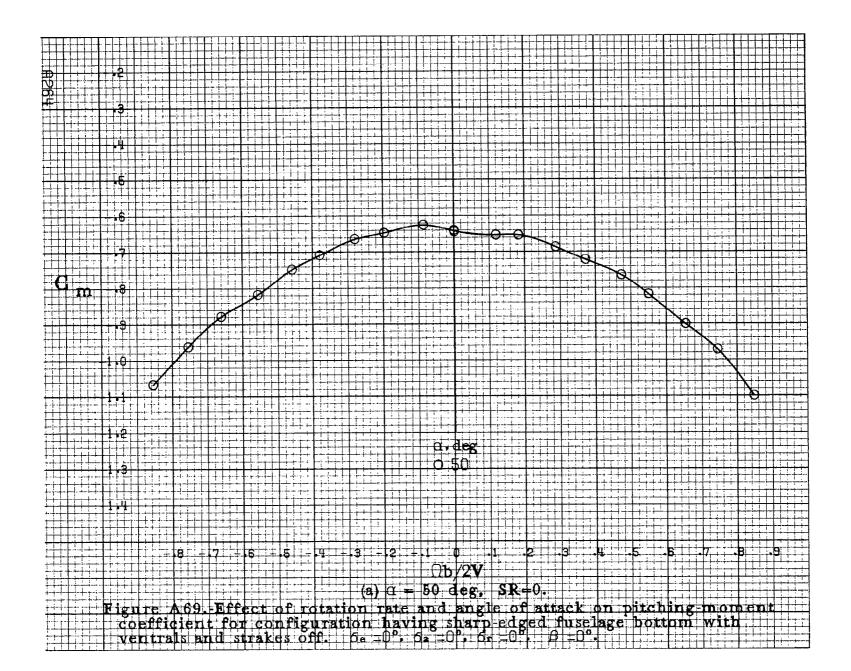


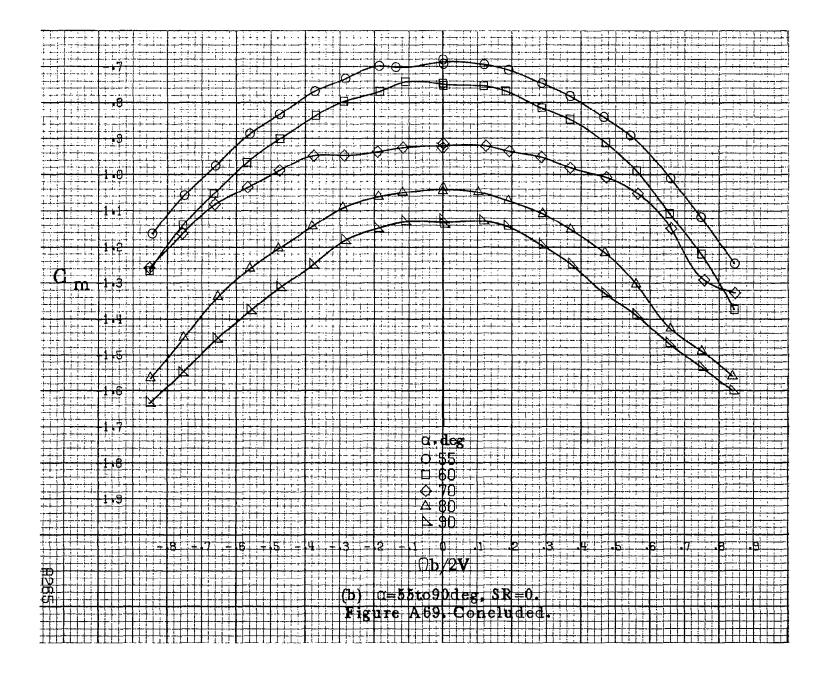


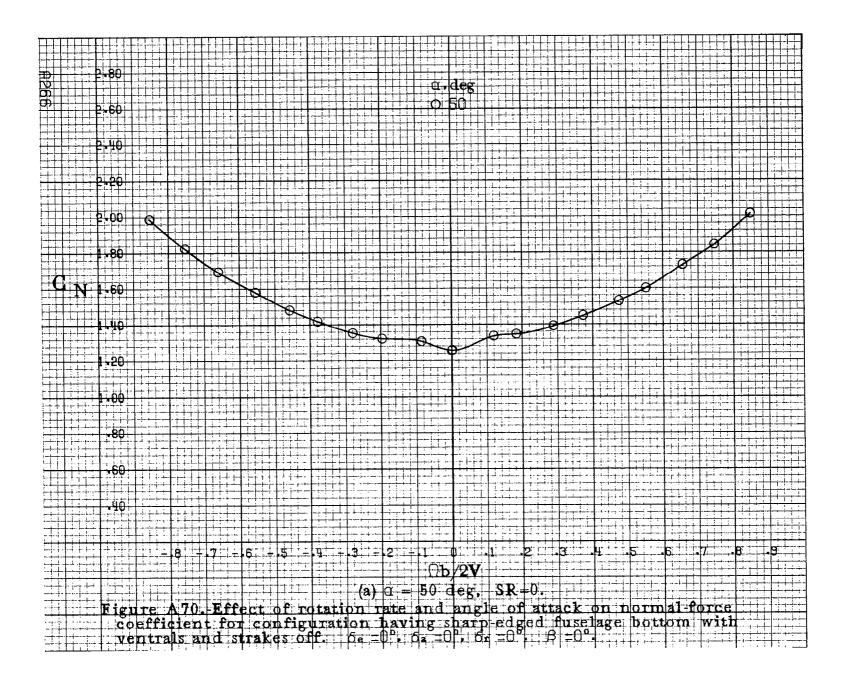


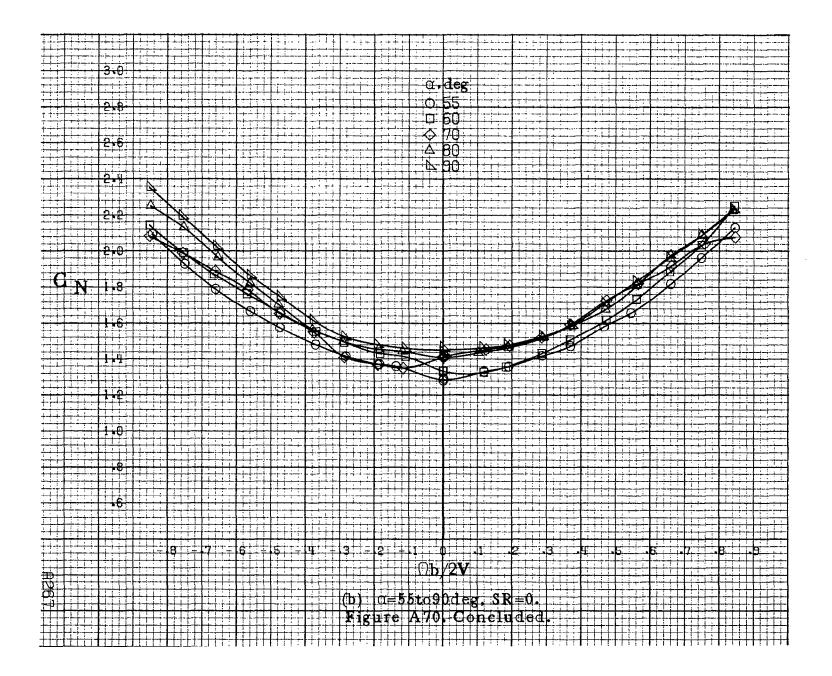


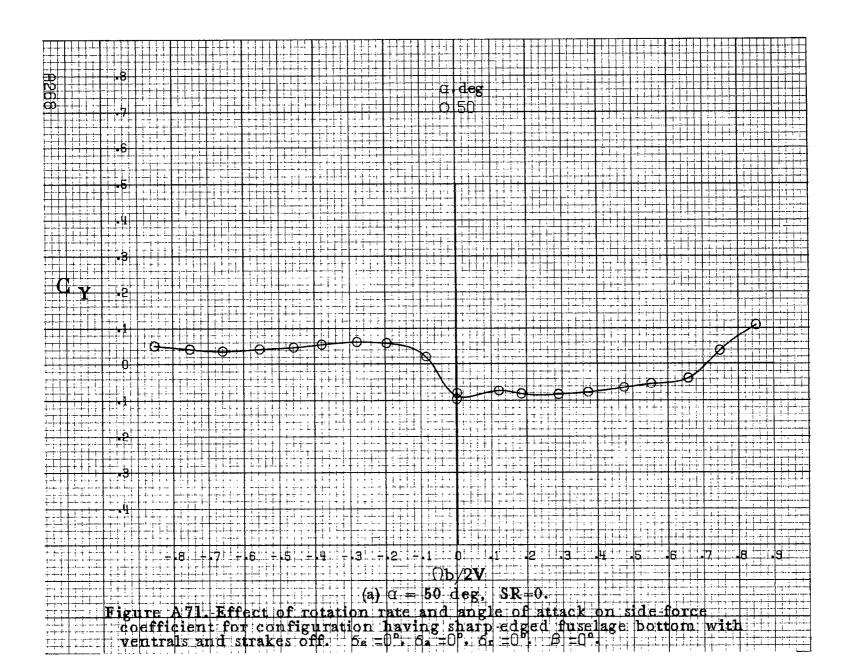


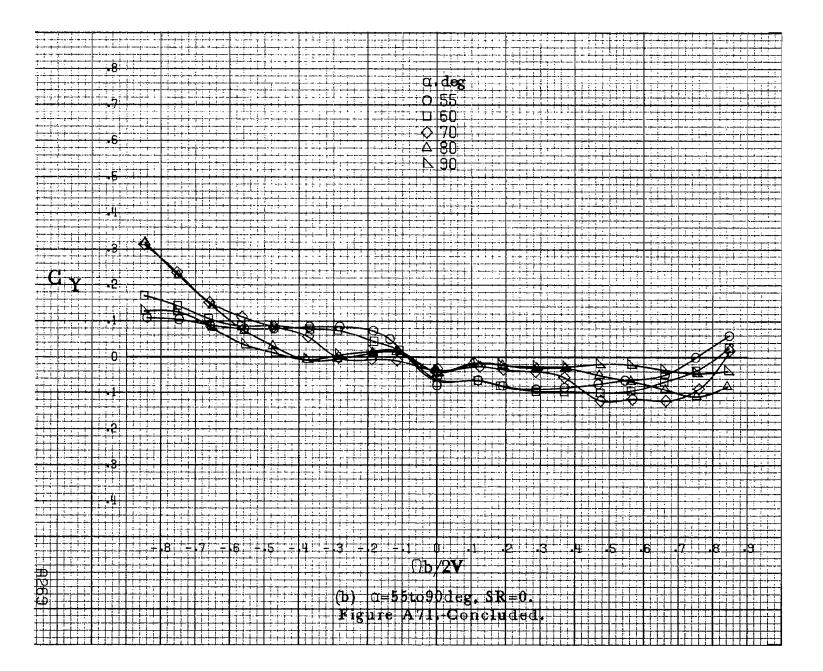


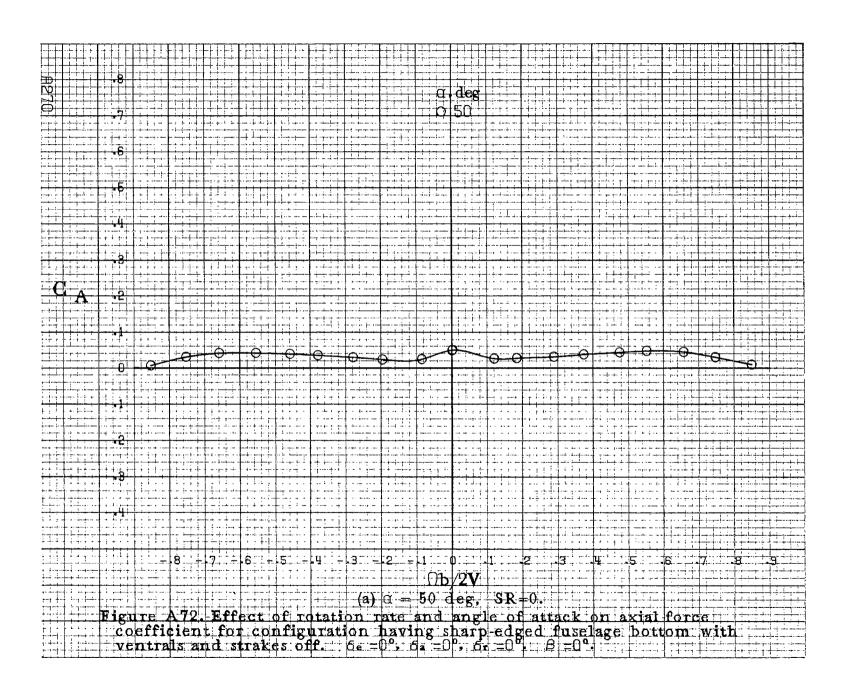


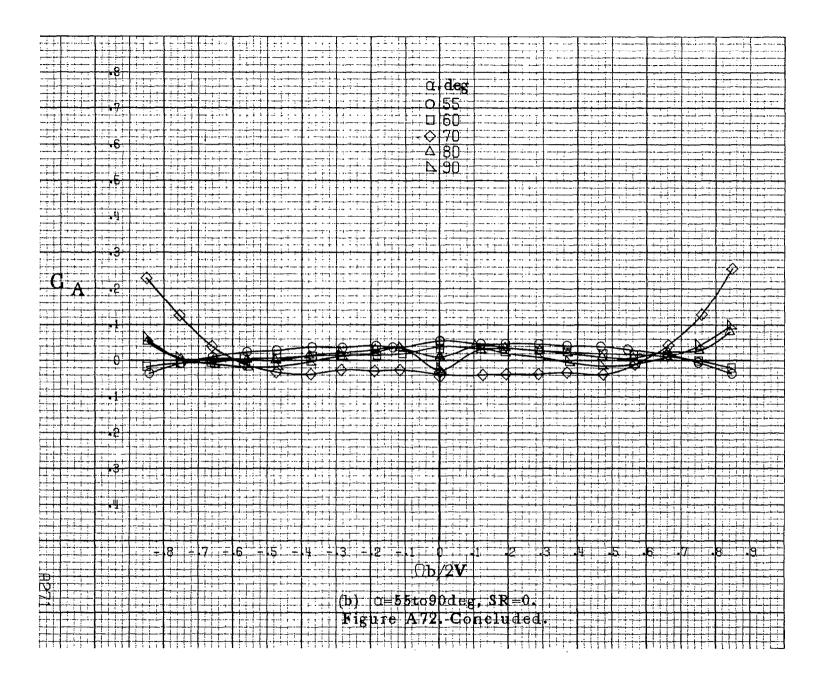


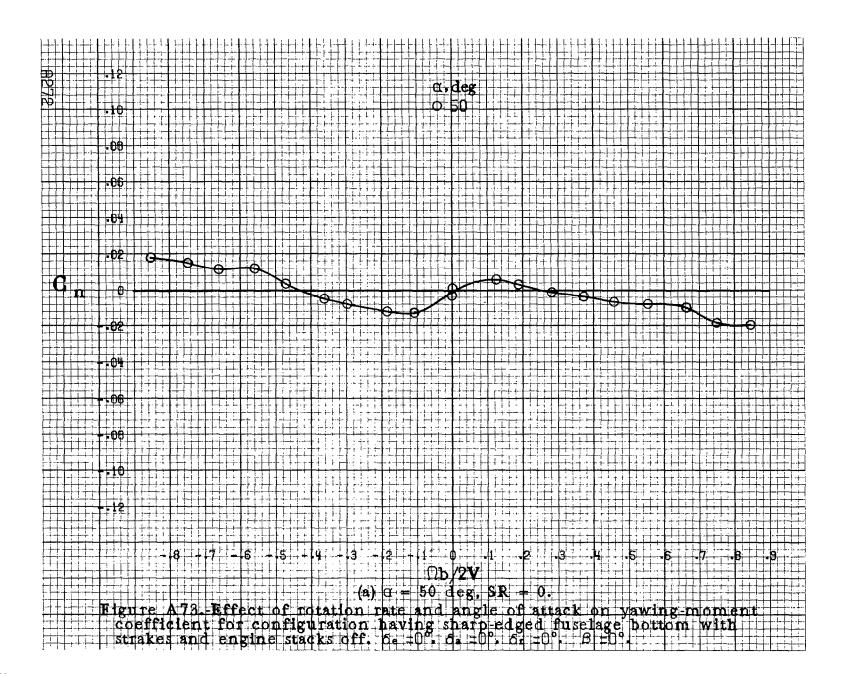


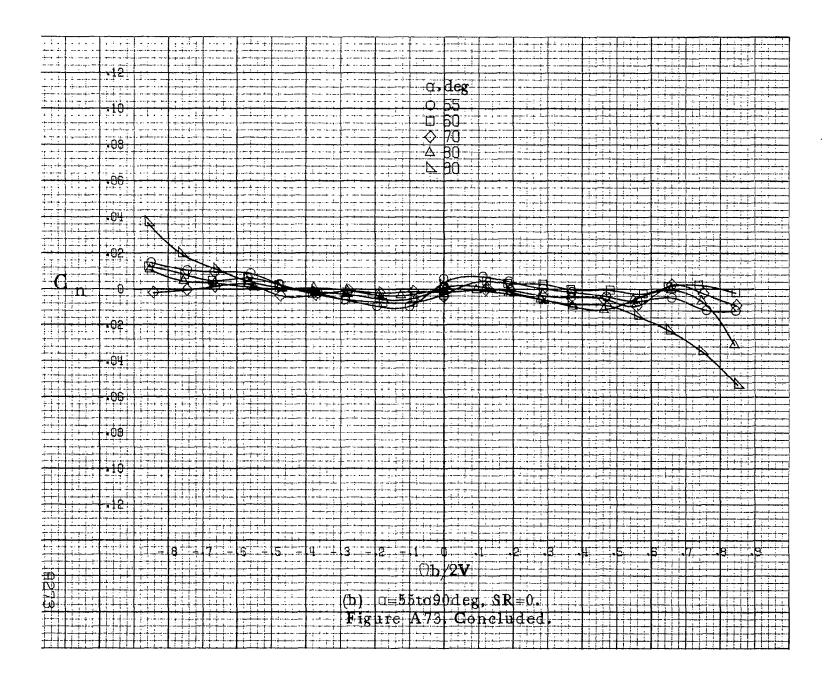


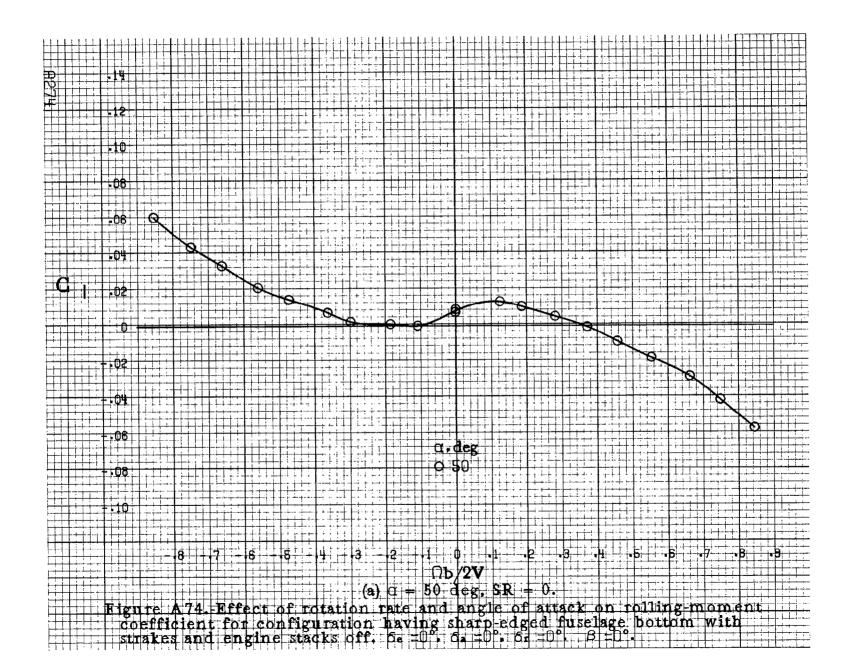


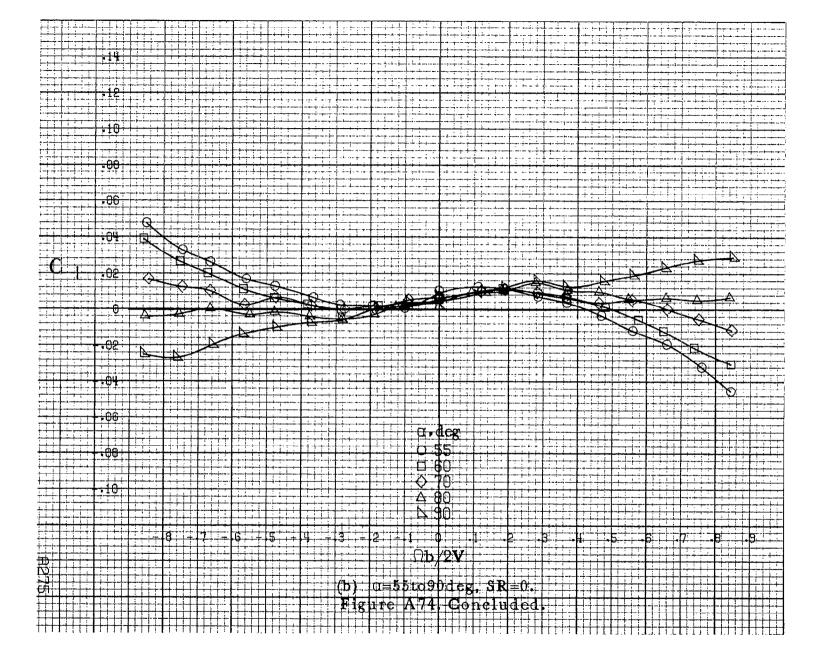


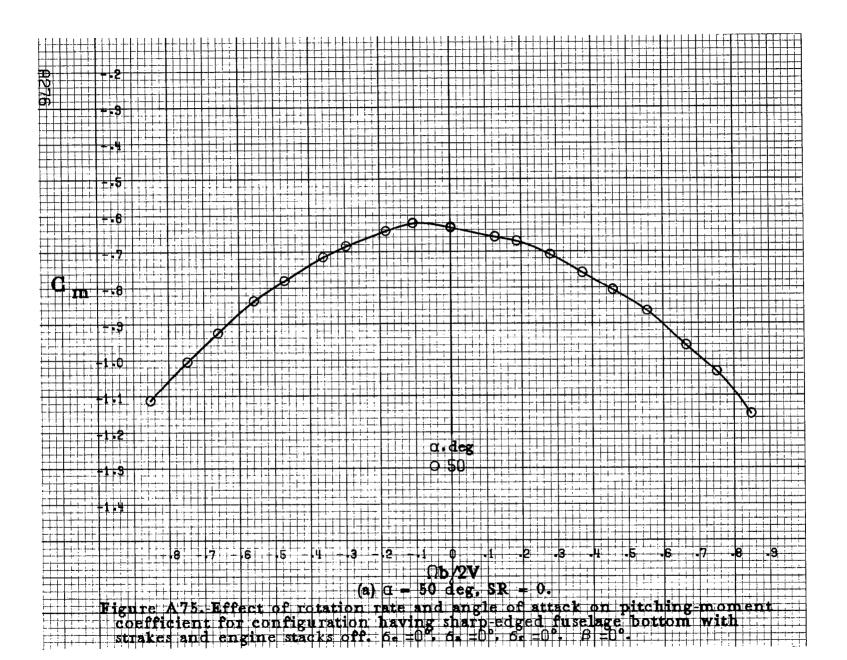




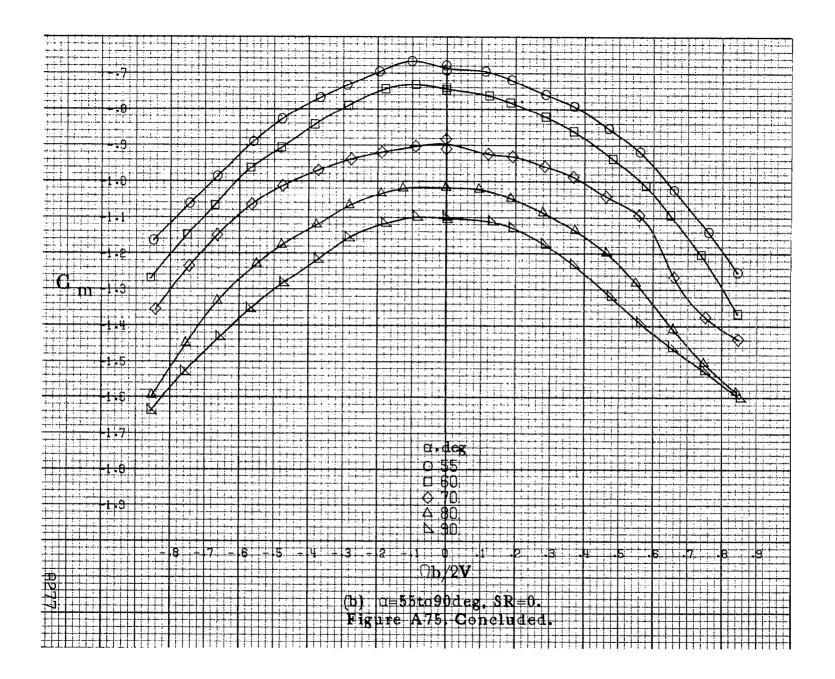


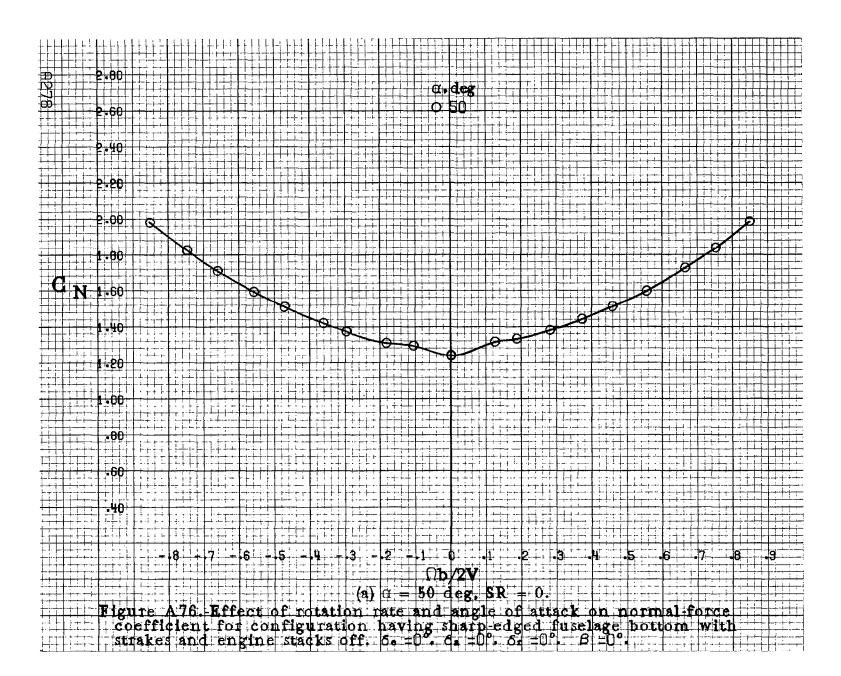


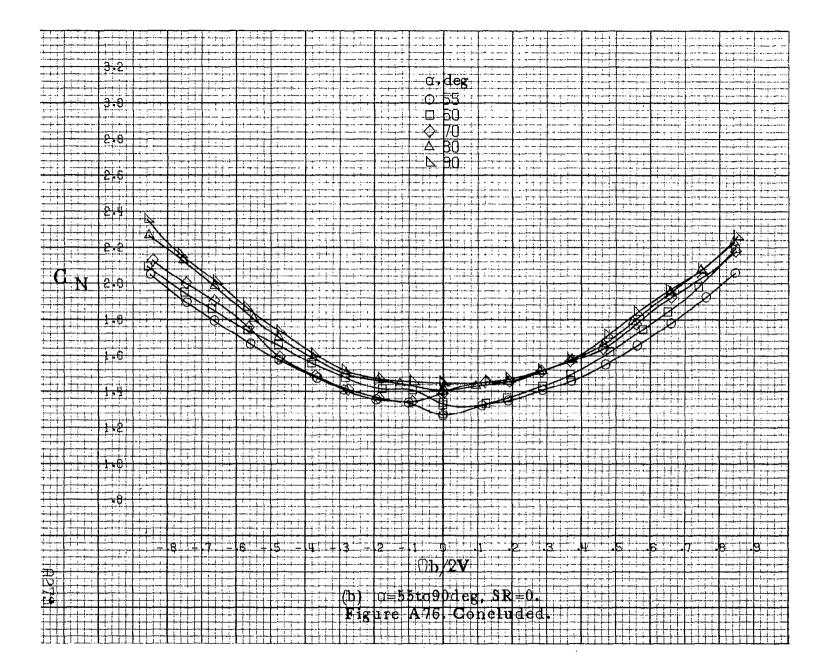


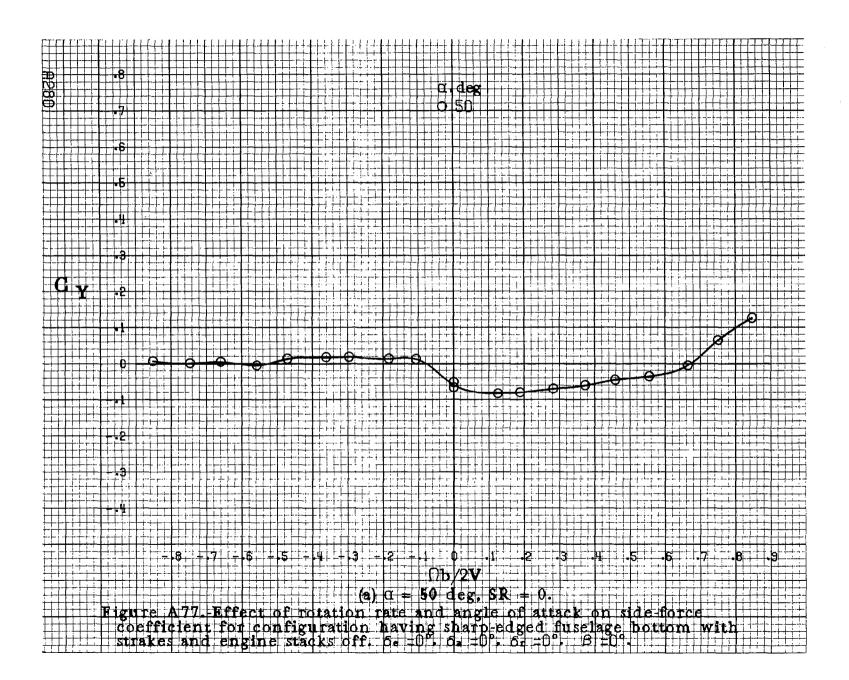


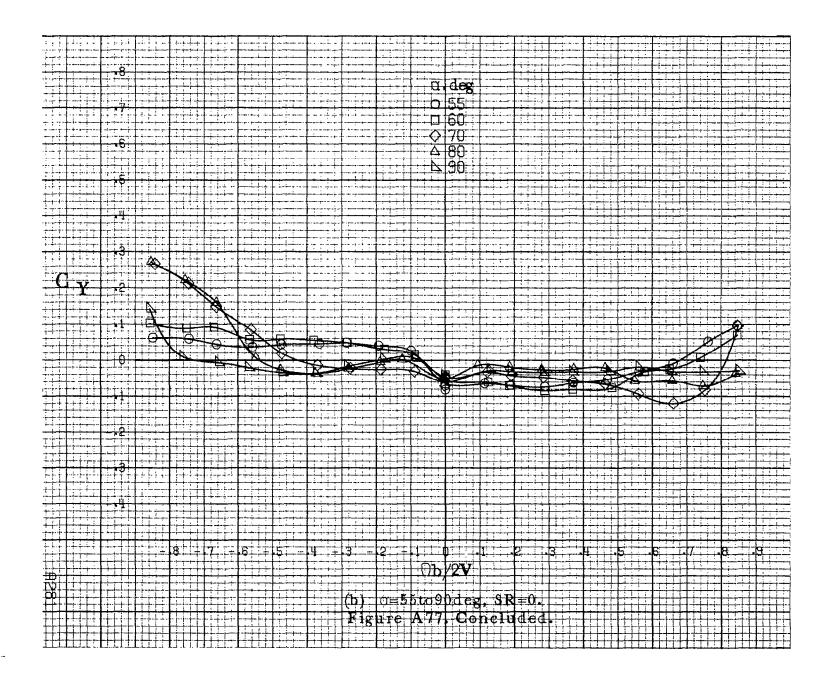
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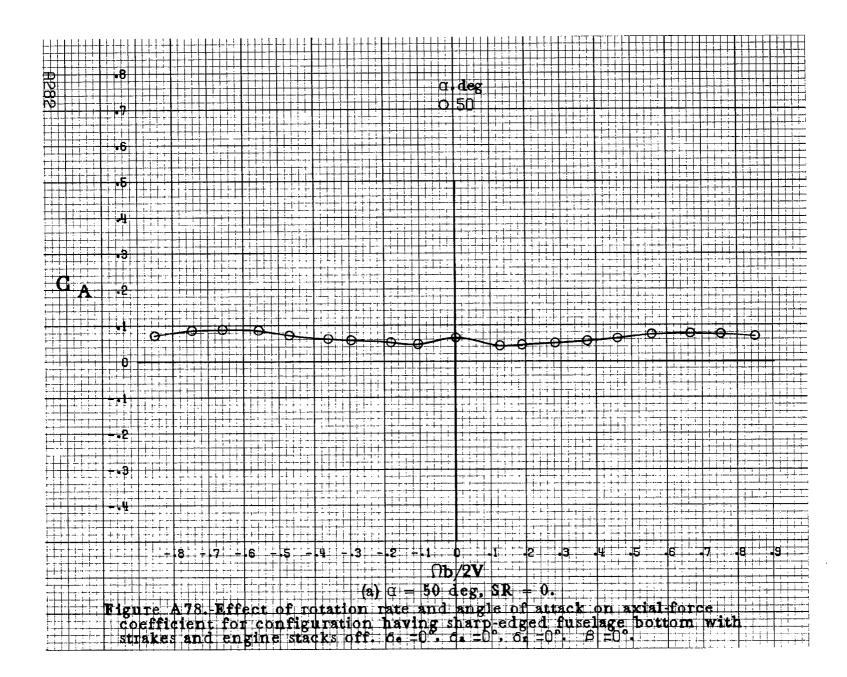


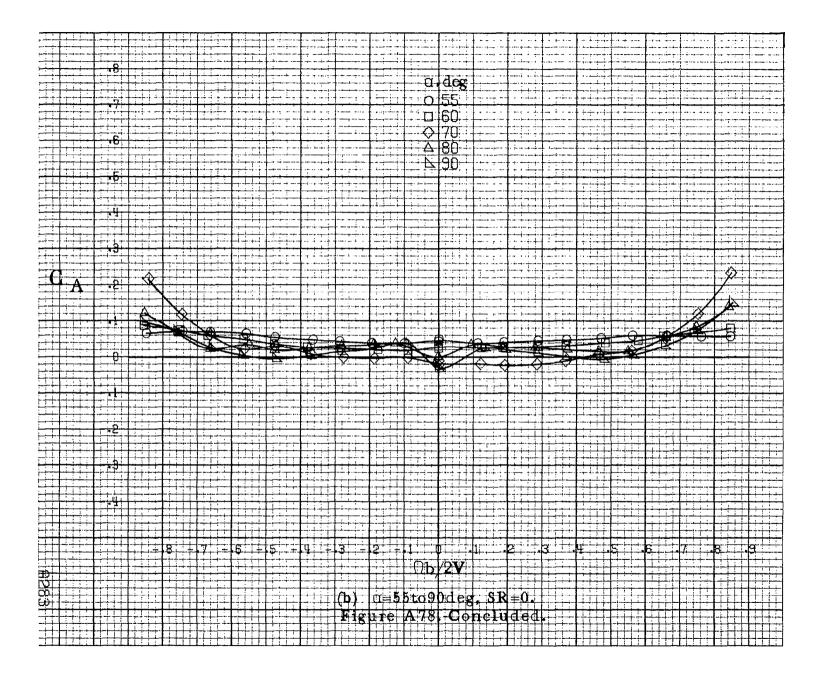


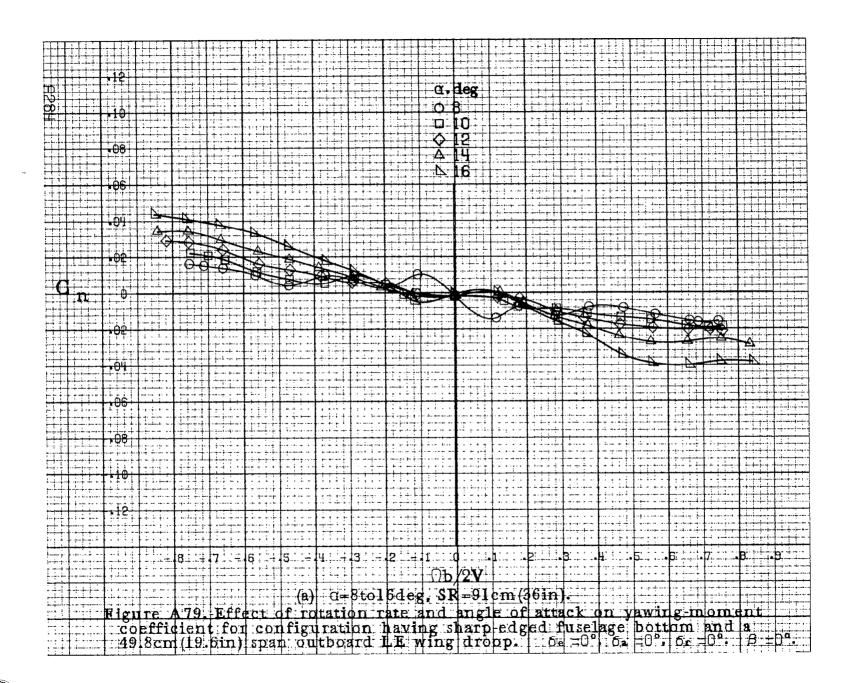


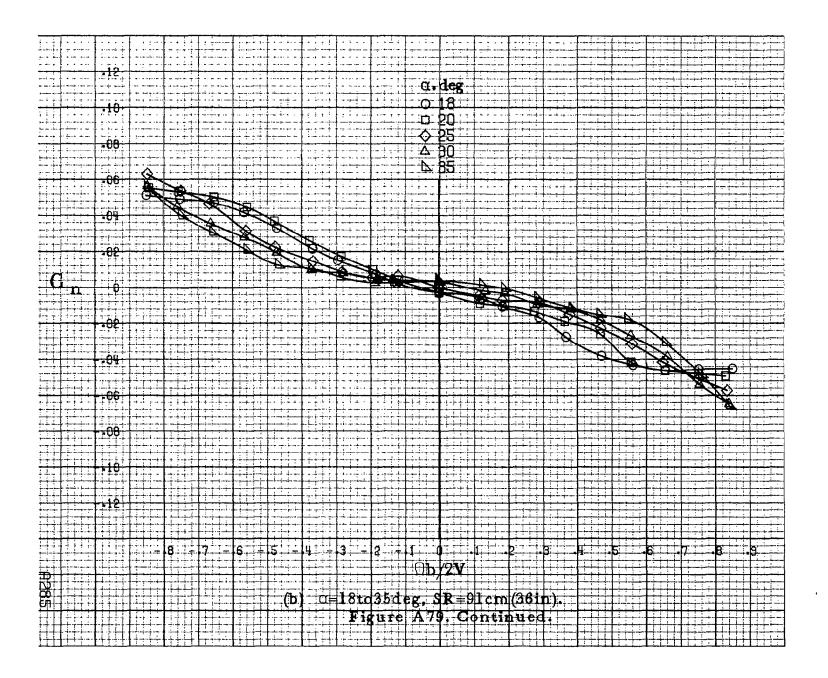


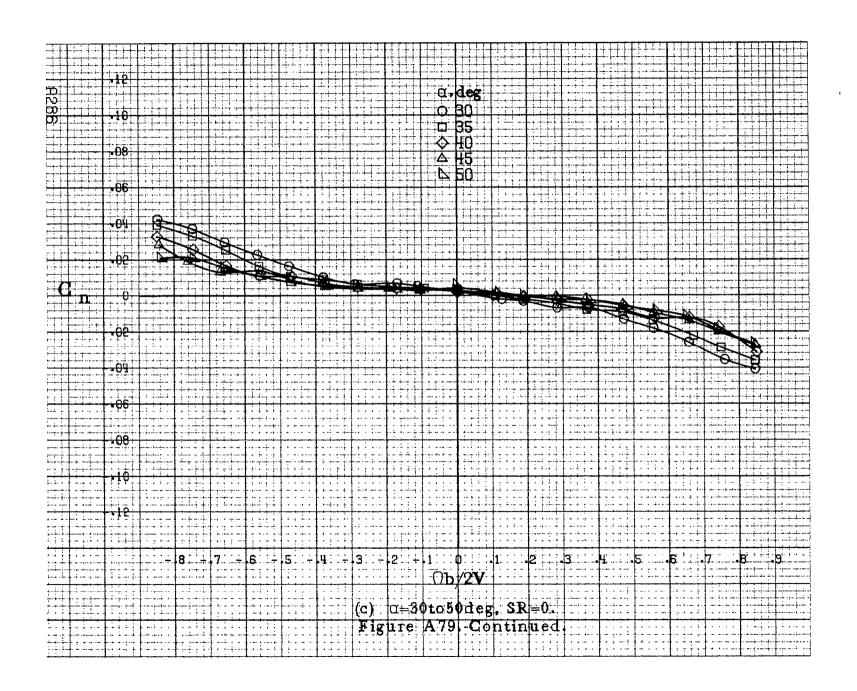


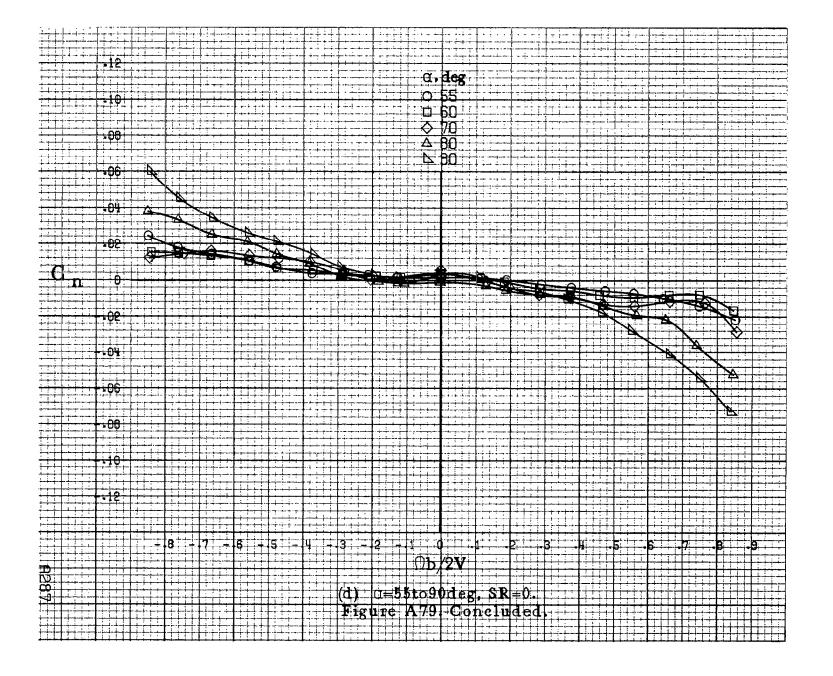


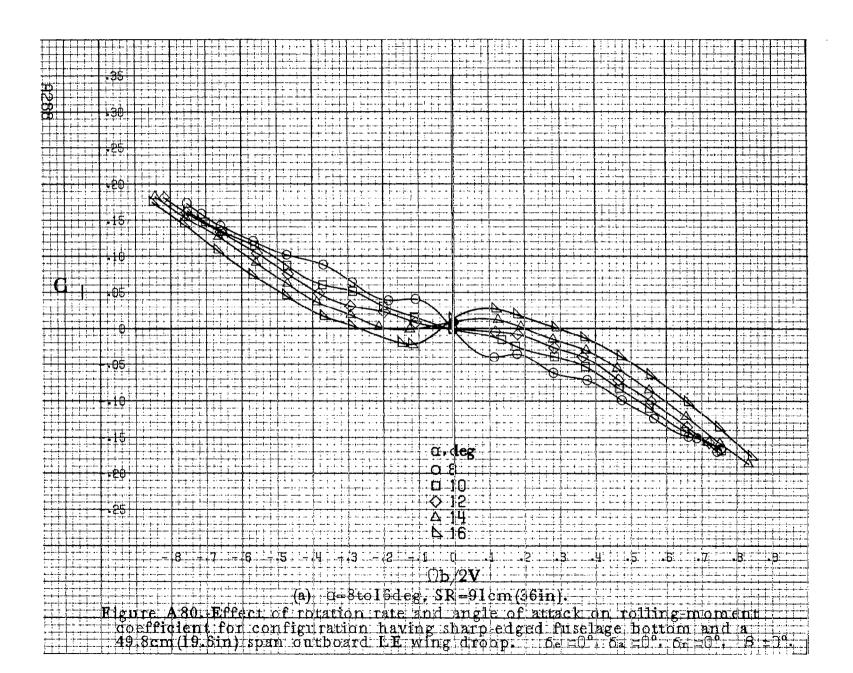


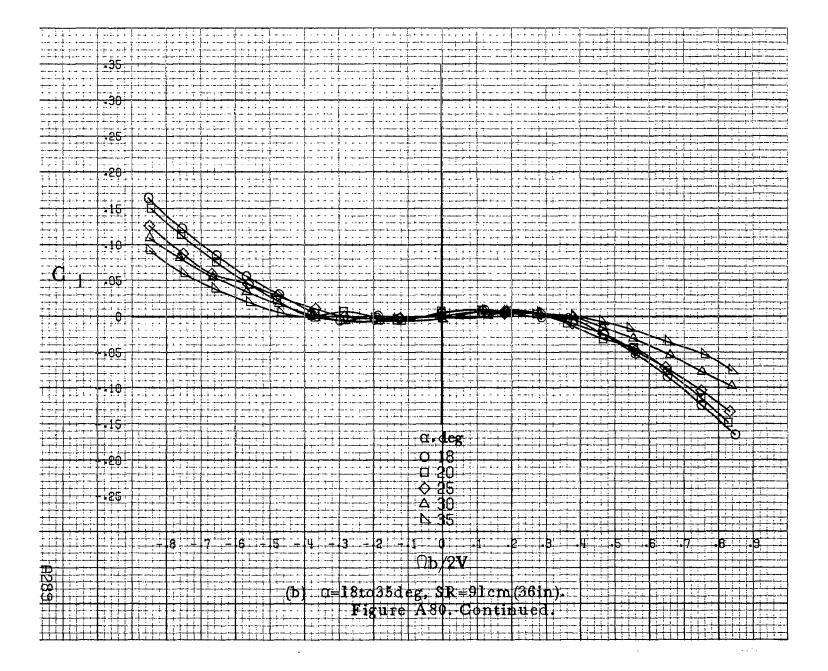


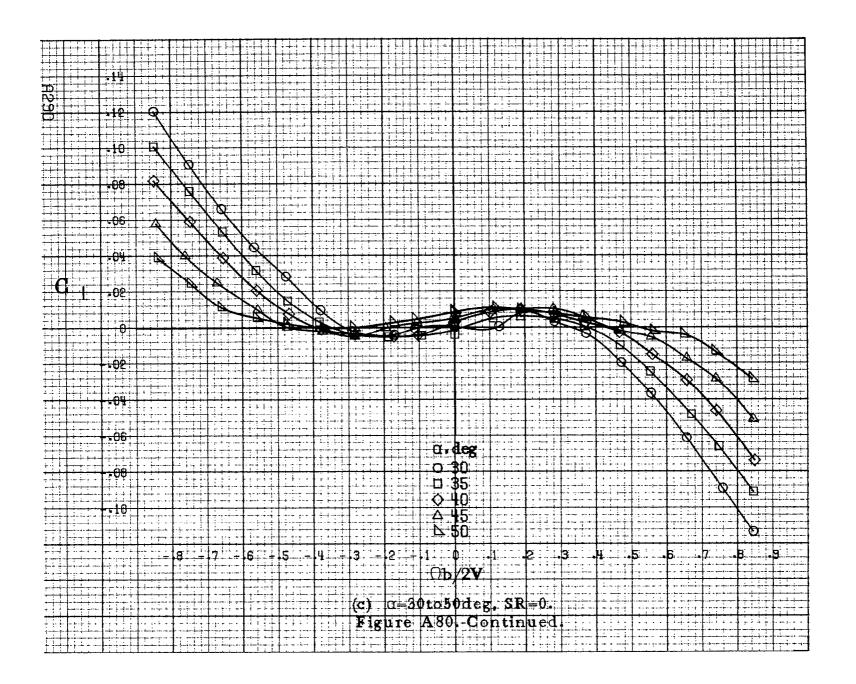


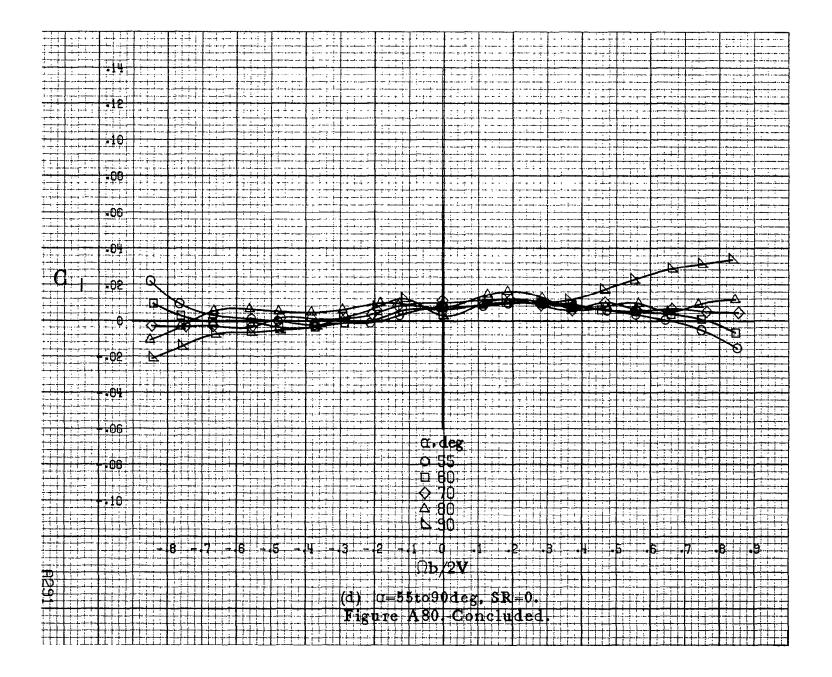


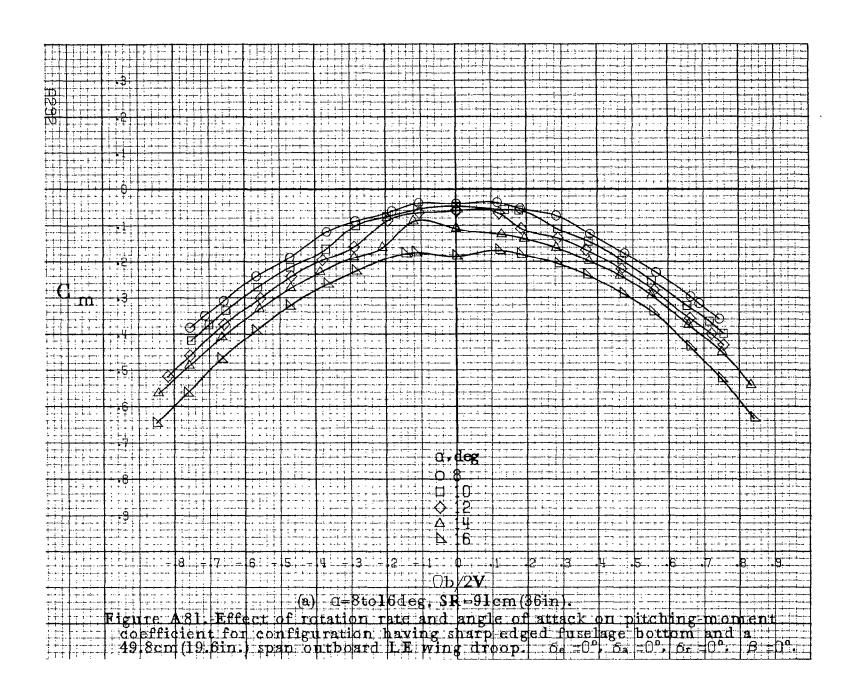


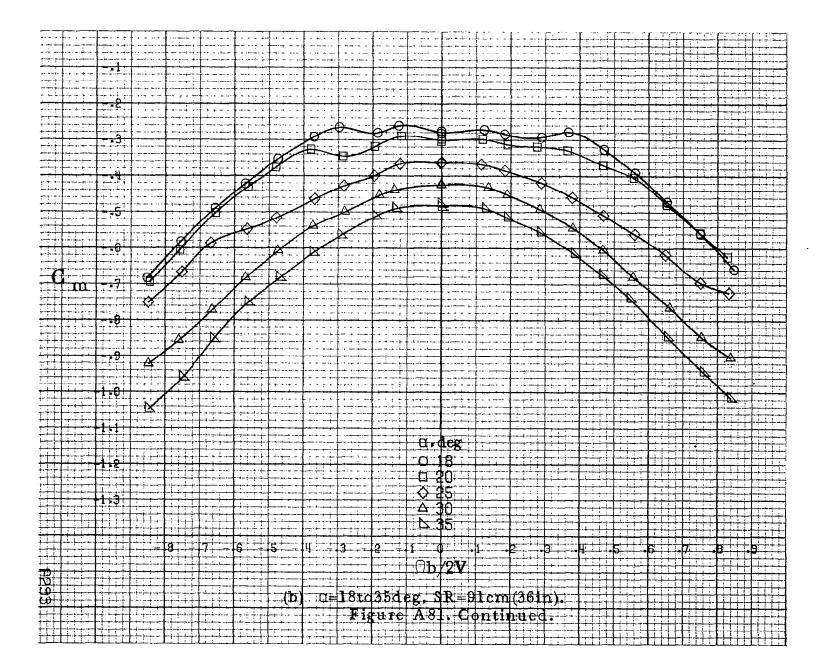


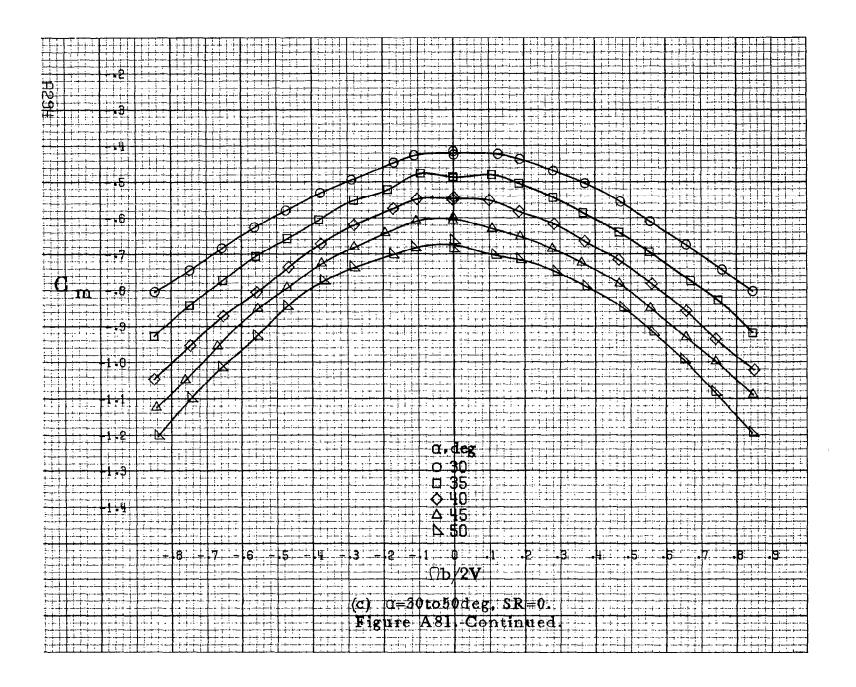


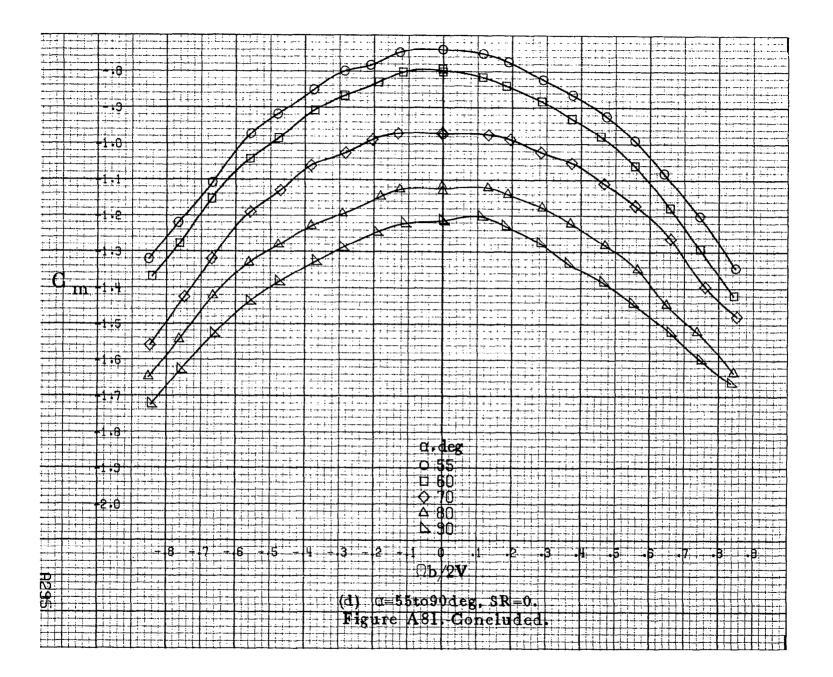


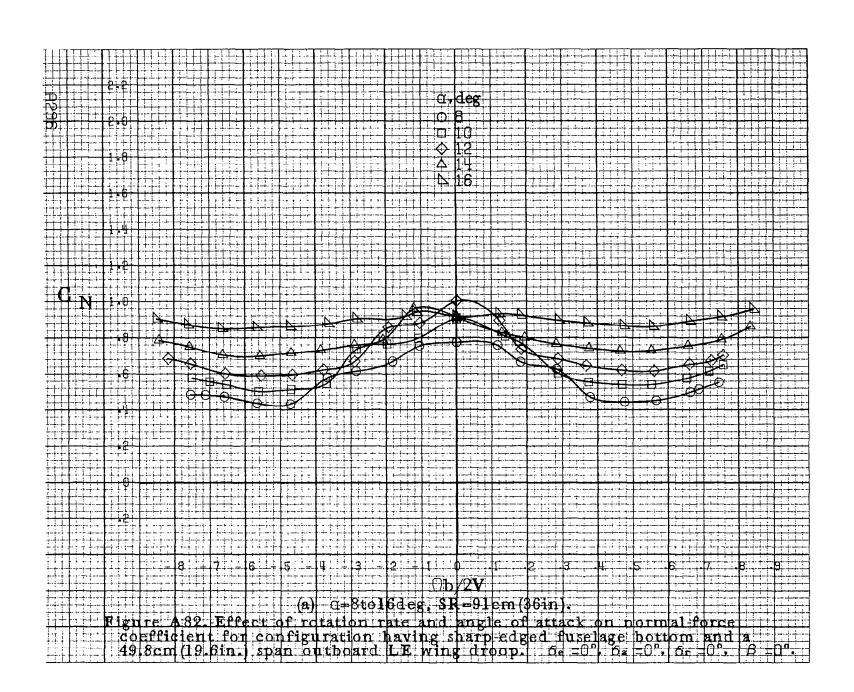




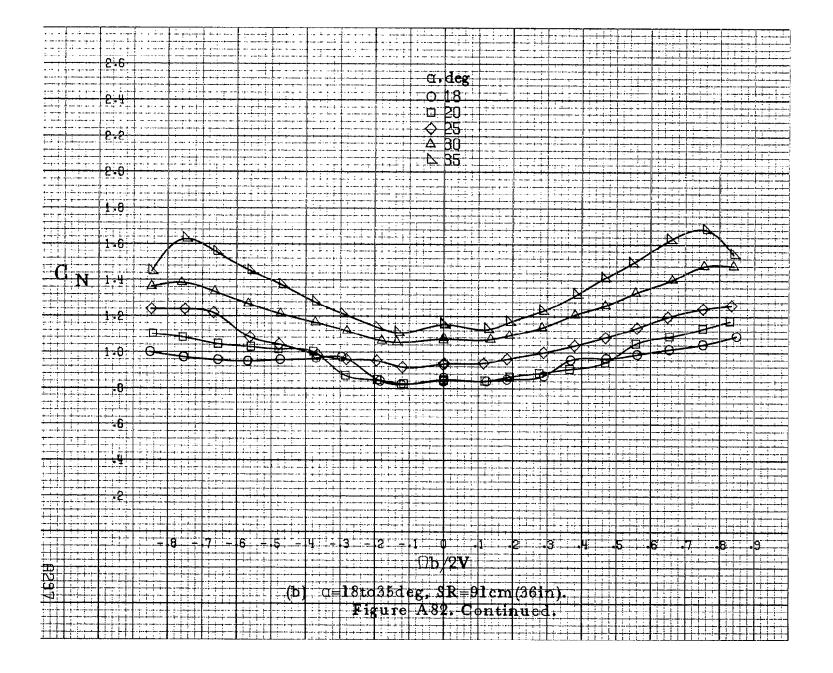


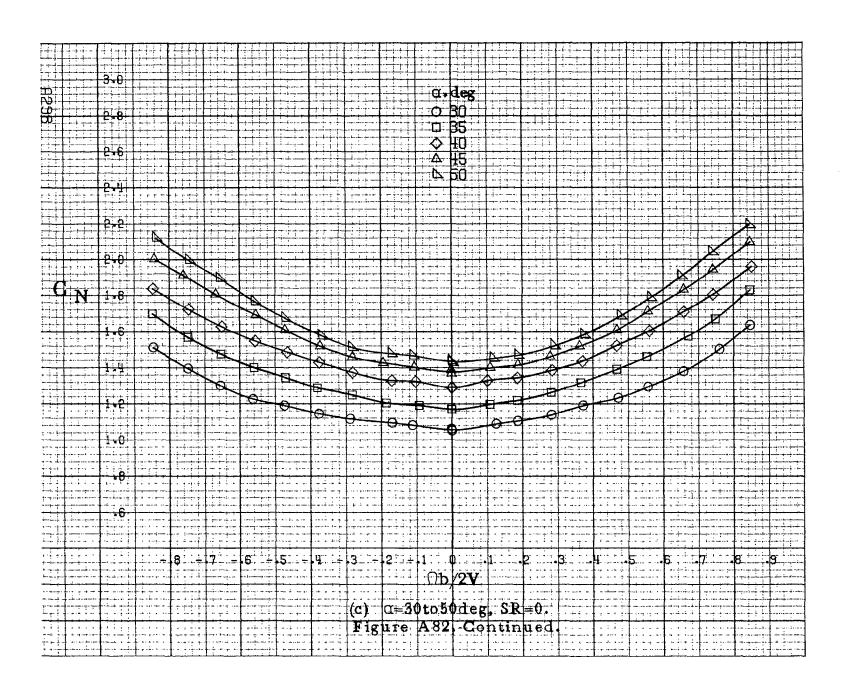


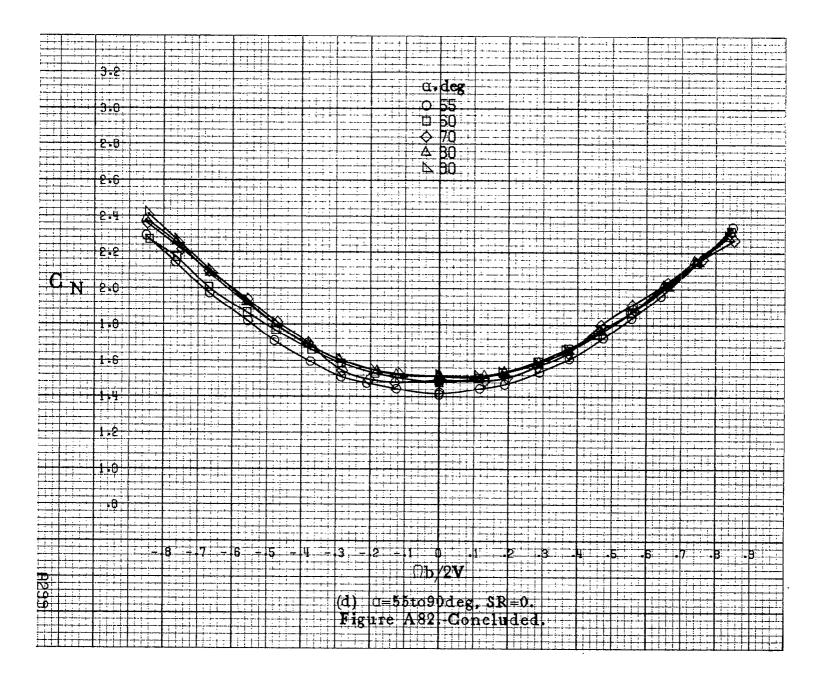


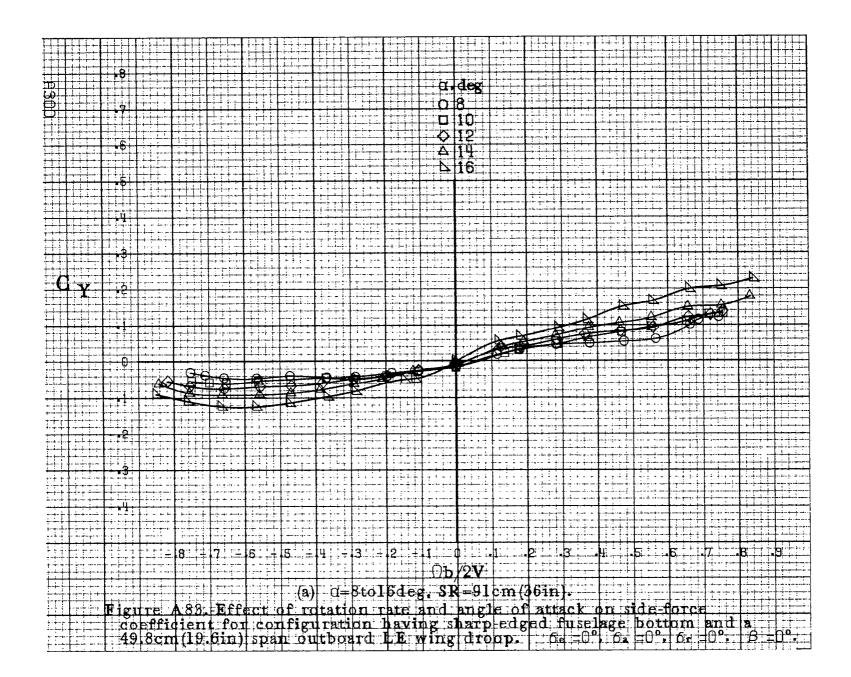


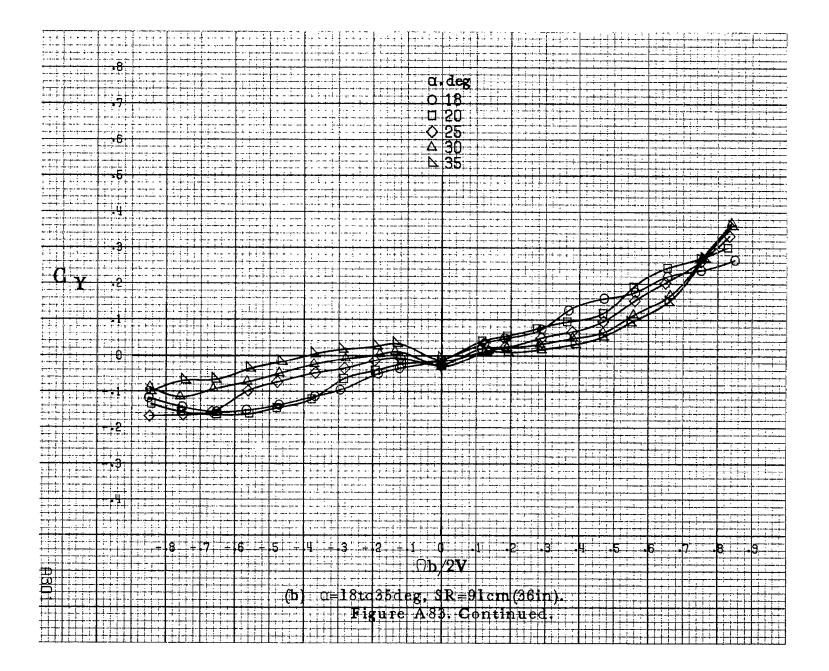


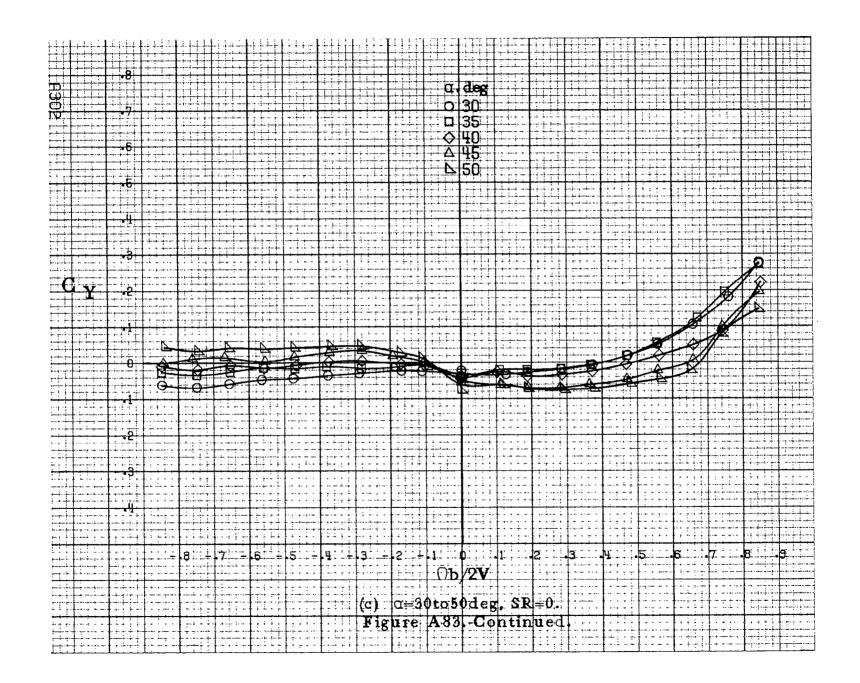


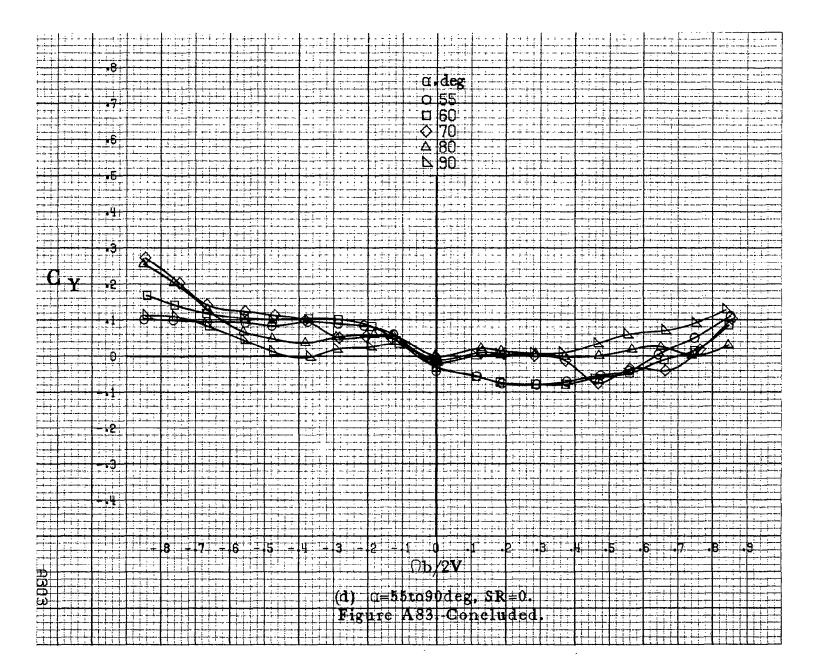


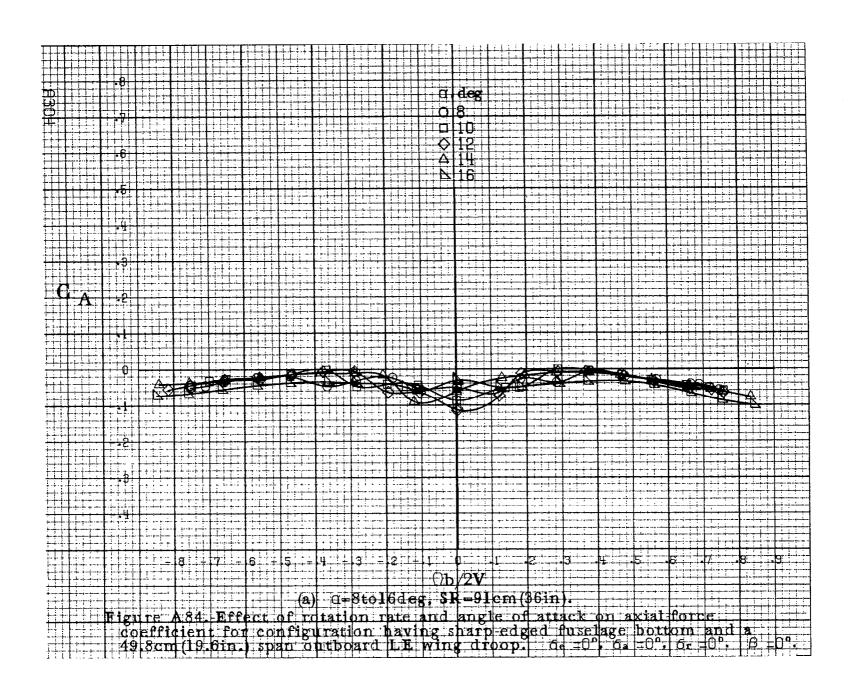








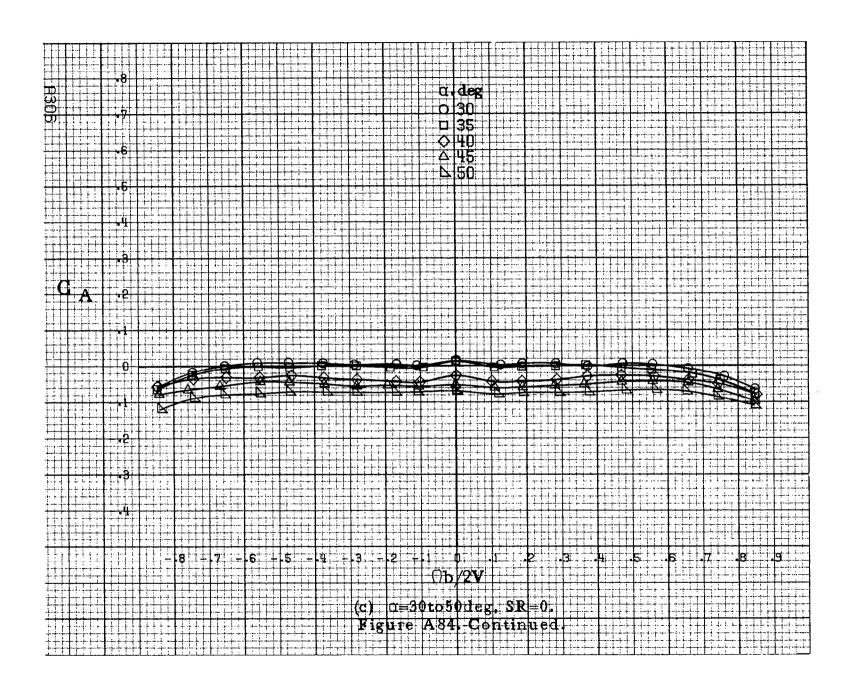




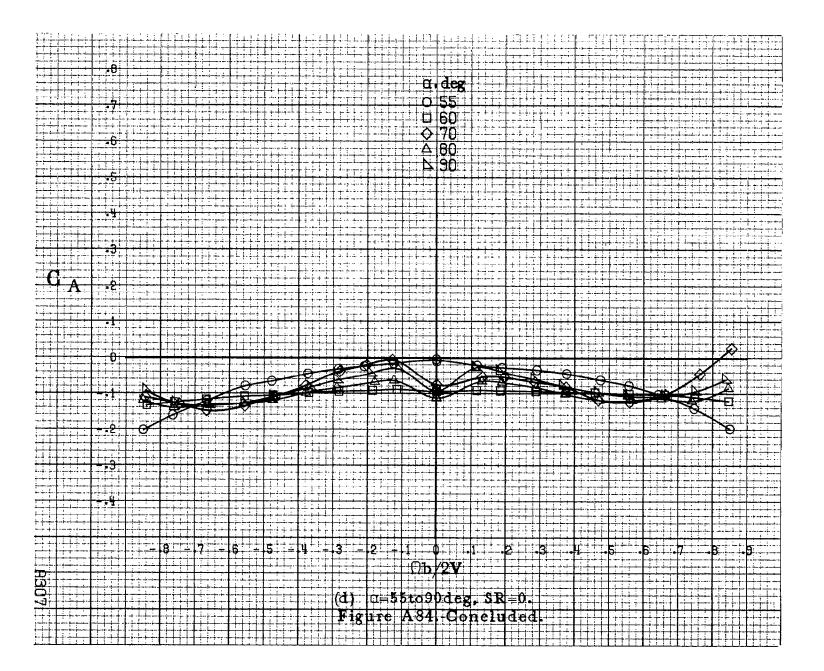
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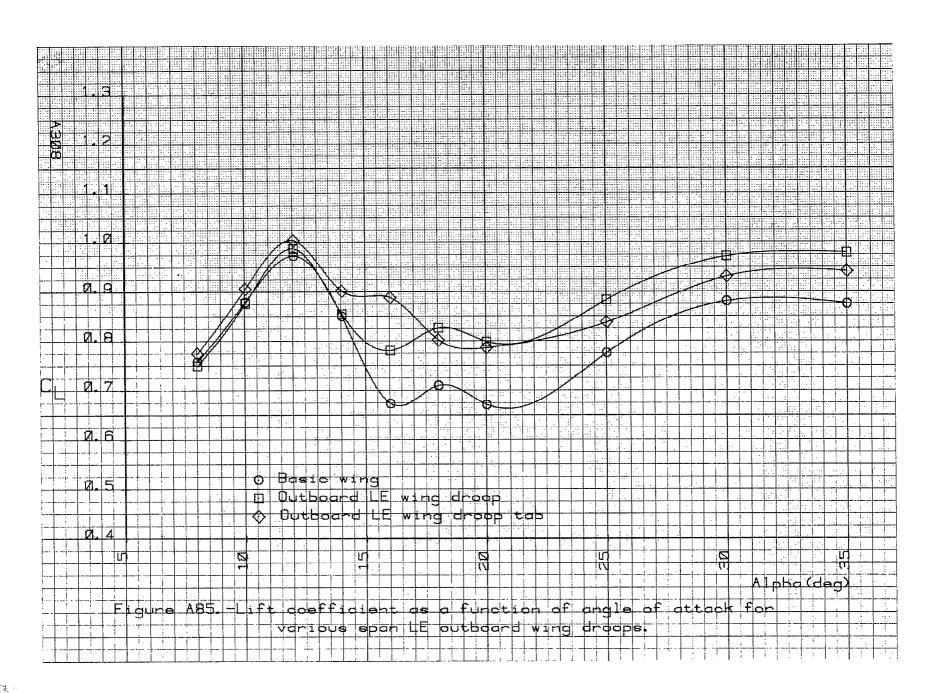
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15.	15. Supplementary Notes Langley Technical Monitor: James S. Bowman, Jr.								
Topical report									
16. Abstract									
	Aerodynamic characte	eristics obtained	in a rot	ational fl	ow er	nvironment utilizing			
	a rotary balance located in the Langley spin tunnel are presented in plotted form								
	for a 1/6-scale, single-engine trainer airplane model. The configurations tested								
	included the basic airplane, various wing leading-edge devices, elevator, aileron								
	and rudder control settings as well as airplane components. Data are presented								
	without analysis for an a	angle-of-attack r	ange of 8	o to 90° a	nd c	lockwise and counter-			
	clockwise rotations cover	- 01							
	CIOCKWISC TOTALIONS COVE	2V Tange	lion o cc	, 0.05.					
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